



PHYTOCHEMICAL STUDY OF THE THREE MAIN ONION VARIETIES (*ALLIUM CEPA* L.) GROWN IN ALGERIA

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Abstract

Three species of Allium cepa (red, purple, yellow) were evaluated for their secondary metabolite content, free radical scavenging activity (DPPH), and ferric reducing ability (FRAP). Our findings confirm that the dry matter content in all varieties ranged from 12.3% to 18.1%, rendering them suitable for extended storage. The ethanolic extract of red onion (EERO) displayed the highest yield (3.86%). Similarly, the levels of total phenols (TPC), total flavonoid content (TFC), hydroxycinnamic acid (HTC), and cysteine-containing peptide (CTC) varied between 0.14 and 0.27 mg/g GAE, 0.20 and 0.29 mg/g QE, 0.25 and 0.29 mg/g GAE, and 0.015 and 0.102 mg CE/g DW, respectively." Furthermore, ethanolic extract of yellow onion (EEYO) demonstrated a significant iron reduction capacity (0.75 ± 0.06 mM Fe²⁺) and an IC₅₀ of 0.159 ± 0.18 mg/ml, indicating enhanced antioxidant potential.

Keywords: Allium Cepa L – variety – secondary metabolites – DPPH - FRAP

1. INTRODUCTION

Originating in Central Asia, the onion (*Allium cepa* L.) is cultivated as an agricultural crop for its foliage and bulbs (Pirat & Foury [1]). It is a fundamental ingredient in recipes worldwide (Mégroz & Baumgartner [2]). The bulb, typically spherical or pear-shaped, with a wide array of features, serves as a nutrient reserve organ supporting the vegetative propagation of the species (Bhattacharjee et al. [3]). The major onion bulb producers in the western region of Africa encompass Niger, Nigeria, Senegal, and Burkina Faso (Schmelzer & Gurib-Fakim [4]). *Allium cepa* bulbs are a well-planted variety and an essential component of many African condiments and sauces. It's one of the world's most prized veggies.

Nutritionally, it provides all sorts of vitamins (B vitamins, vitamin C, provitamin A), inorganic salts (potassium, sodium, zinc, iron, phosphorus, selenium, magnesium, manganese, calcium), fats, proteids, carboids, essential oils, organic acids, fibers (Cigual [5]). Therapeutically, multiple studies have revealed that systematic intake of fresh onions influences blood coagulation, protects against serious metabolic health problems (hypocholesterolemic, hypolipidemic, antithrombic effects), colorectal, stomach and prostate cancers (Bianchini & Vainio; You & Li; Graf et al. [6-8]).

The preventive effect relies on organosulfur compounds (thiosulfinates), that impede carcinogenic effects. (Corzo-Martínez et al. [9]). In this context, our research focuses on assessing the antioxidant properties through Ferric Reducing Antioxidant Power and 2,2-diphenyl-1-picrylhydrazyle tests, alongside quantifying secondary

metabolites in three various cultivars (red, purple and yellow) widely cultivated in Algeria -Sidi Bel Abbès-.

2. MATERIALS AND METHODS

Biological material

Three *Allium cepa* varieties - red (Rd), yellow (Ylw), and violet (Prl) - were selected. Freshly harvested bulbs, uniform and flawless, were stored at 4°C before analysis. In the lab, bulbs were cleaned, peeled, diced, and oven-dried (Ecocell) at 40°C for 4 days. Subsequently, they were ground using an electric grinder (IKA), and the powder was collected after sieving.

Non-biological materials

The Folin-Ciocalteu reagent (99.8% purity), quercetin (99%), ascorbic acid (99%) and DPPH (92%) are sourced by Sigma Chemical Co (St. Louis, MO, USA), while the high-purity chemicals (>98%) are by Merck (Darmstadt, Germany)".

Physical and chemical analyses

Determination of dry matter

5gr of onion slices were weighed in baskets before and after oven drying at 105°C overnight (16-18 h).

The overall solid content was calculated by subtracting the water content.

Ash content

For ash determination, 5 g of onion slices were calcined in a muffle furnace at 550°C for 30 minutes.

Acidity

Thirty milliliters of 95% ethanol were mixed with five grams of ground onion, and the combination was agitated at 25°C for an hour. Subsequently, it was centrifuged for five minutes at 3500 rpm. For qualitative

phytochemical screening, 20 milliliters of the resulting supernatant were titrated with 0.1N NaOH, employing a color indicator (Trease and Evans, 1987 [10]).

Phytochemical screening (qualitative)

To extract, 5 grams of each sample powder were boiled in 100 ml of water. After a 15-minute, the suspension was filtered to obtain 100 cc of filtrate (Trease & Evans [10]).

Hydrolysable tannins test

5 ml of 5% infusion from each sample was placed in a glass container, followed by the addition of 1 ml of 1% FeCl₃. The emergence of a greenish or blue-black color indicates reactivity.

Condensed tannins test

To assess condensed tannins, 1 ml concentrated hydrochloric acid was mixed with 5 ml infusion of each sample and boiled for 10 minutes. The presence of a red precipitate, soluble in amyl alcohol, is a sign of responsiveness.

Anthocyanins test

Ammonium hydroxide (NH₄OH) and sulfuric acid (5 ml each) were added to 5 ml of infusion of each sample. The coloration is enhanced by acidity when anthocyanins are present, and in a basic medium, the coloration changes to purplish blue.

Free quinones test

Add 0.1 milliliter of 1% NaOH to 1 milliliter of extract from all of the samples. There are free quinones exist when the color turns yellow, red, or purple.

Anthraquinone

To 1ml of extract of each sample, 1ml of ammonia (NH₄OH 10%) is added. After shaking, the purple coloration indicates their presences.

Saponosides

Samples (1%) were decocted by boiling 1 g of powder in 100 ml water for 15 minutes. The filtered suspension (1-10 ml) was added incrementally to ten test tubes filled with water. The tubes were vigorously shaken horizontally for 15 seconds, and foam height was measured after 15 minutes. For each tube, the foam height was evaluated.

Quantification of different compounds

Producing the alcohol-based extract

10 g onion powder of each species was soaked in ethanol and stirred for 24 h at ambient conditions (Majhenic et al. [11]). The solution was treated on evaporation equipment (Heidolph instruments). The extract was then dried in an oven: the three extracts resulting EERO: ethanolic extract of red onion; EEYO: ethanolic extract of yellow onion; EEPO: ethanolic extract of purple onion, these extracts were kept at 4°C until required.

Total polyphenols content (TPC)

0.2 ml of each extract was added to a solution consisting of 1 ml diluted Folin-Ciocalteu reagent and 0.8 ml 7.5% Na₂CO₃, according to Singleton et al. [12] process.

The reading was taken at 765 nm with Gallic Acid as reference. Values were reported in milligrams of gallic acid equivalents (GAE) per gram of dry extract, calculated from the equation of the calibration curve

($y = 46.41x + 0.063$; $R^2 = 0.988$).

Total flavonoids content (TFC)

The AlCl₃ colorimetric method involves diluting 0.5 ml of each extract in 2 ml of distilled water, then successively adding 0.15 ml of 5% NaNO₂, 0.15 ml of 10% AlCl₃ and 2 ml of 4% NaOH. The volume was adjusted to 5 ml with distilled water. Absorbance at 510 nm was read after 15 minutes of incubation (Kanzawa et al. [13]). Quercitrin served as the reference for the calibration curve. Results, calculated using the curve's equation ($y = 46.41x + 0.063$; $R^2 = 0.988$), were expressed as mg quercitrin equivalent per gram of dry extract (mg QE/g DE).

Hydrolysable tannins content (HTC)

For Hydrolysable Tannins Content (HTC) involved mixing tannin extract with FeCl₃, creating a red-purple complex via Fe³⁺ ion interaction. A solution containing FeCl₃ (0.01M) and HCl (0.001M) (v/v) was combined with each extract. Absorbance was read at 660 nm after 15 seconds (Mole & Waterman [14]). HTC calculation

$$HT\% = OD \cdot \frac{M \cdot V}{E_{moles} \cdot SW} \quad (1)$$

HT%: percentage of hydrolysable tannins; OD: optical density; M : 300 ; V : volume of extract used ; E_{moles}: 2169 d'acide gallique ; SW: sample weight.

Condensed tannins content (CTC)

Three milliliters of 4% vanillin were mixed with volumes of each sample ranging from 0.1 to 0.5 milliliters. 1.5 cc of HCl was swiftly introduced and thoroughly shaken after the initial vigorous shaking. After 20 minutes of incubation, absorbance was taken at 500 nm (Julkunen-Titto [15]). The outcomes were presented to be mg of catechin equivalent per gram of dry extract (mg CE/g DE) utilising a calibration curve with catechin as a reference under comparable conditions.

Antioxidant activity via DPPH free radical scavenging

DPPH radical scavenging was assessed following Benhamou et al.'s method [16]. Five distinct concentrations were made available and 50 µl of samples was introduced into 1.95 ml of freshly made methanolic DPPH solution (0.0025 g/l). A negative control was created similarly using 50 µl of methanol with DPPH. After incubation in darkness for 30 minutes at ambient conditions, readings were taken at 515 nm.

Ferric reducing antioxidant power (FRAP)

FRAP test, as outlined by Oyaizu et al. [17], utilized 0.25 ml of individual extract concentrations. These were mixed with 0.625 ml of 0.2 M phosphate buffer (pH: 6.6) and 0.625 ml of 1% K₃Fe(CN)₆ solution. After 20 minutes at 50°C, 0.625 ml of 10% TCA halted the reaction. Subsequently, the supernatant (0.625 ml) was blended with 0.625 ml distilled water and 0.125 ml of a 0.1% FeCl₃ solution. Measured at 700 nm using ascorbic acid as the reference.

Statistical analysis was conducted via Microsoft Excel 2010. Feedings were reported as mean ± standard

deviation, with significance set at $p < 0.05$. All measurements were performed in triplicate.

3. RESULTS AND DISCUSSIONS

Physico-chemical characteristics

The outcomes concerning the physical and chemical characteristics of the three onion types are detailed in Table 1.

Table 1. Physicochemical parameters of the different varieties of *Allium cepa*

Parameters (%)	RO	YO	PO
DM	17.6±0.0	12.3±0.0	18.1±0.0
Ashes	1.9±0.005	2 ±0.006	1.1±0.006
Acidity	3,33±0,15	3,23±0,15	3,1±0,2

DM: Dry matter; RO: Red onion; YO: Yellow onion; PO: Purple onion

Based on our findings, the three varieties have DM contents that vary between (12.3 to 18.1%), these values remain comparable to those reported by (Stadlmayr [18]) (12 to 13%) and (Konate et al. [19]), (9.63 ±0.38 to 17.97±0.45%). Several studies indicate that the levels of dry matter (DM) typically fluctuate between 7% and 18% of fresh weight based on the onion variety (Abhayawick et al. [20]). Interestingly, a positive relationship has been established between an onion's capacity for long-term storage and the dry matter content within the bulbs (Ko et al. [21]).

Onions containing higher levels of dry matter tend to exhibit greater firmness, thus offering increased resistance during transportation and handling, reducing susceptibility to damage (Silué et al. [22]).

Such damages, if incurred, could serve as entry points for parasites or microorganisms, ultimately leading to bulb rot. Consequently, the varieties under investigation demonstrate characteristics suggesting they possess significant potential for extended storage.

Regarding ash content, the onion varieties exhibited variations ranging from 1.1% to 2%. These findings differ from those reported by Nwinuka et al. [23] and Konate et al. [19], where ash content was reported to range from 4.8±0.15% to 2.50% to 6.64%, respectively.

The acidity levels among the various varieties appear comparable, ranging from 3.1 to 3.3%.

Nevertheless, these readings are notably higher compared to those documented by Konate et al. [19], which ranged from 0.27 to 0.40%. This discrepancy might arise from the abundance of acid (propanethial-S-oxide) in our varieties. When this compound is exposed to ocular moisture, it transforms into sulfuric acid.

Phytochemical screening (qualitative)

The findings from the phytochemical examination of the three onion varieties are depicted in Table 2.

Table 2. Phytochemical screening of different varieties of *Allium cepa* L (Mean ± SD; n=3).

Phytochemical substances	RO	YO	PO
Total tannins	+++	-	++
Condensed tannins	+++	+++	+++
Flavonoids /Anthocyanins	-	-	-
Anthraquinone	+++	++	++
Quinones	++	+++	++
Saponosides			
Foam height (cm)	<1	<1	<1
Foam index	<100	<100	<100

RO: Red onion; YO: Yellow onion; PO: Purple onion ; Very positive: +++ ; moderately positive: ++; positive: +; negative: -

Our findings indicate the existence of distinctive secondary constituents including tannins, anthracene derivatives and saponins, which are distinctive of onions. These outcomes align with research conducted by Mangambu et al. [24] and Arora et al. [25]. Likewise, Oyewusi et al. [26] upheld the presence of flavonoids, alkaloids, tannins and saponins in the methanolic extract of onions *Allium cepa* L. However, anthocyanins, known for their antioxidant properties beneficial for UV protection and plant health, were undetected in our extracts.

Phytochemical screening (quantitative)

Table 3 shows the quantification of the various secondary metabolites of the three onion varieties.

Table 3. Secondary metabolites of various *Allium cepa* L. extracts (Mean ± SD; n=3)

Parameters	EEEO	EEYO	EEPO
TPC mg EAG/g DM	0.23±0.005	0.14±0.03	0.27±0.02
TFC mg QE /gr DM	0.29±0.02	0.20 ±0.01	0.25±0.01
HTC mg EAG/g de DM	0.29 ±0.002	0.25 ±0.021	0.26±0.031
CTC mg CE/g DM	0.015 ±0.008	0.078±0.007	0.102±0.012
Yield (%)	3.86	0.61	3.79

EEEO : ethanolic extract of red onion ; EEYO : ethanolic extract of yellow onion ; EEPO : ethanolic extract of purple onion ; CE: Catechin equivalent; GAE: Gallic acid equivalent; QE: Quercetin equivalent; TFC: Total flavonoid content; TPC: Total phenolic content; HTC : Hydrolysable tannins content ; CTC: Condensed tannins content

The Total Phenolic Content (TPC) among the three extracts exhibited a range from 0.14 to 0.27 mg, with a maximum of 0.27 ± 0.02 mg EAG/g DM, consistent with findings by Benkeblia [27], who reported levels ranging from 0.18 to 0.20 mg/g fresh weight in red onions. Similarly, the concentration of total phenolic compounds varied notably in *Allium* extracts, spanning from 0.84 to 2.07 mg/g DM, surpassing our recorded results (Nuutila et al. [28]).

Flavonoids, renowned for their anti-inflammatory and analgesic properties in medicinal plants such as onions (Aliyu et al. [29]), exhibit varying contents in our findings, measuring approximately (0.29 ± 0.02 vs 0.20 ± 0.01 vs 0.25 ± 0.01) for EERO, EEYO, and EEPO, respectively. Tannins, widely prevalent across numerous plant species, serve as a defense against predation and potentially function as pesticides, contributing to growth regulation.

The present study confirms the existence of Hydrolysable Tannins (HT) in all three extracts, reaching a peak of 0.29 ± 0.002 in EERO, while EEPO displayed the highest concentration of Total Tannins (TC) at 0.102 ± 0.012 mg EC/g DM. The variations observed in bioactive compounds within the three extracts likely stem from variances in genetic makeup, notably the cultivar (Bajaj et al. [30]).

Regarding antioxidant activity, the DPPH test serves as a rapid screening method for identifying antioxidant molecules within plant extracts. Similarly, the assessment of antioxidant potency through iron reduction presents as a facile and reproducible method, widely employed to discern the most active extracts (Rodríguez-Bonilla et al. [31]). The results derived from the DPPH and FRAP tests conducted on the three alcoholic extracts of *Allium cepa* L. are delineated in Table 4.

Table 4. Free radical-scavenging activities and ferric reducing ability of ascorbic acid and ethanolic extracts of different *Allium cepa* L (Mean $\pm$ SD; n=3).

Extract	DPPH IC ₅₀ *(mg/ml)	FRAP** (mM Fe ²⁺)
EERO	0.204 ± 0.017	$0,48 \pm 0,09$
EEYO	0.159 ± 0.18	$0,75 \pm 0,06$
EEPO	0.265 ± 0.014	$0,66 \pm 0,05$
Vit C	0.132 ± 0.002	$1,37 \pm 0,07$

Values were the means of three replicates $\pm$ standard deviation. *IC₅₀ value (mg/ml of extract), inhibitory concentration 50%; DPPH radicals were scavenged by 50%; **Determined at 1 mg/ml ; EERO : ethanolic extract of red onion ; EEYO : ethanolic extract of yellow onion ; EEPO : ethanolic extract of purple onion.

These two trials validate EEYO's superior antioxidant potential, showcasing an IC₅₀ of (0.159 ± 0.18 mg/l) and Ferric Reducing Capacity (0.75 ± 0.06 mM Fe²⁺), trailed by EERO (0.204 ± 0.017 mg/l vs 0.48 ± 0.09 mM Fe²⁺) and EEPO (0.265 ± 0.014 mg/l vs 0.66 ± 0.05 mM Fe²⁺). This underscores the impact of onion variety on Alliums' antioxidant prowess. However, the antioxidant performance of Alliums is contingent upon phenolic and sulfur compounds (Miller et al. [32]), cultivation techniques, and extraction procedures (Prakash et al. [33]). Moreover, the varying sensitivity of reagents utilized in the antioxidant assessment methods (DPPH, FRAP) may elucidate the disparities observed among the studied extracts.

CONCLUSIONS

This investigation underscores the secondary metabolite richness within Algeria's primary onion varieties. The evaluation of antioxidant potential through diverse methodologies demonstrates a convergence in outcomes.

REFERENCES

- [1] Pitrat M., Foury C. Histories of vegetables: their origins at the start of the 21st century. *Histories of vegetables: their origins at the start of the 21st century* 2003.
- [2] Mégroz N., Baumgartner A. The onion, good to taste and the eye. *A Loupe* 2000; 2: 1-4.
- [3] Bhattacharjee S., Sultana A., Sazzad M. H., Islam M.A., Ahtashom M., Asaduzzaman M. Analysis of the proximate composition and energy values of two varieties of onion (*Allium cepa* L.) bulbs of different origin: A comparative study. *International Journal of Nutrition and Food Sciences* 2013; 2(5): 246-253.
- [4] Schmelzer G. H., Gurib-Fakim A. Medicinal Plants, vol. 11. *Wageningen, The Netherlands: Plant Resources of Tropical Africa (PROTA)*.
- [5] Cical. 2020. National Agency for Food, Environmental and Occupational Health Safety. Table of nutritional composition of foods. Accessed on 14/09/2020.
- [6] Bianchini F., Vainio H. Allium vegetables and organosulfur compounds: do they help prevent cancer? *Environmental health perspectives* 2001; 109(9): 893-902.
- [7] You WC, Li JY. Etiology and prevention of gastric cancer: a population study in a high risk area of China. *Chin. J. Dig Dis* 2005; 6(4): 149-154.
- [8] Graf BA., Milbury PE., Blumberg JB. Flavonols, flavones, flavanones and human health: epidemiological evidence. *J Med Food* 2005; 8(3):281-90.
- [9] Corzo-Martínez M., Corzo N., Villamiel M. Biological properties of onions and garlic. *Trends in food science & technology* 2007; 18(12): 609-625.
- [10] Trease GE., Evans WC. *Pharmacology* 11th Ed. Bailliere Tindall Ltd, London 1978; 60-75.
- [11] Majhenič L., Škerget M., Knez Ž. Antioxidant and antimicrobial activity of guarana seed extracts. *Food chemistry* 2007; 104(3):1258-1268.
- [12] Singleton VL., Orthofer R., Lamuela-Raventós R. M. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In *Methods in enzymology* 1999; 299:152-178.
- [13] Kanazawa K., Hashimoto T., Yoshida S., Sungwon P., Fukuda S. Short photoirradiation induces flavonoid synthesis and increases its production in postharvest vegetables. *Journal of agricultural and food chemistry* 2012; 60(17): 4359-4368.
- [14] Mole S., Waterman P.G. A critical analysis of techniques for measuring tannins in ecological studies. *Oecologia* 1987; 72(1): 137-147.
- [15] Julkunen-Titto R. Phenolic constituents in the levels of northern willows: methods for precursors of clarified apple juice sediment. *J. Food Sci* 1985; 33 : 254-257.
- [16] Benhammou N., Atik Bekkara F., Kadifkova P.T. Antioxidant activity of methanolic extracts and some bioactive compounds of *Atriplex halimus*. *Comptes Rendus Chimie* 2009; 12 (12): 1259-1266.
- [17] Oyaizu M. Studies on products of browning reactions: Antioxidative activities of product of browning reaction prepared from glucosamine. *Japanese Journal of Nutrition and Dietetics* 1986; 44(6): 307-315.

- [18] Stadlmayr B. West African food composition table/table de composition des aliments d'Afrique de l'Ouest 2012.
- [19] Konate M., Parkouda C., Tarpaga V., Guira F., Rouamba A., Sawadogo-Lingani H. Evaluation des potentialités nutritives et l'aptitude à la conservation de onze variétés d'oignon (*Allium cepa* L.) bulbe introduites au Burkina Faso. International Journal of Biological and Chemical Sciences 2017; 11(5) : 2005-2015.
- [20] Abhayawick L., Laguerre J.C., Tauzin V., Duquenoy A. Physical properties of three onion varieties as affected by the moisture content. Journal of Food Engineering 2002 ; 55(3) : 253-262.
- [21] Ko S.S., Huang J.W., Wang J.F., Shanmugasundaram S., Chang W. N. Evaluation of onion cultivars for resistance to *Aspergillus niger*, the causal agent of black mold. Journal of the American Society for Horticultural Science 2002; 127(4) : 697-702.
- [22] Silué S., Fondio L., Coulibaly M.Y., Magein H. Sélection de variétés d'oignon (*Allium cepa* L.) adaptées au nord de la Côte d'Ivoire. Tropicultura 2003; 21(3):129-134.
- [23] Nwinuka N. M., Ibeh G. O., Ekeke G. I. Proximate composition and levels of some toxicants in four commonly consumed spices 2005.
- [24] Mangambu M. D. D., Mushagalusa, K. F., Kadima N.J. Contribution à l'étude photochimique de quelques plantes médicinales antidiabétiques de la ville de Bukavu et ses environs (Sud-Kivu, RD Congo). Journal of Applied Biosciences 2014; 75: 6211-6220.
- [25] Arora E., Sharma V., Khurana A., Manchanda A., Sahani D., Abraham S., Chiru L. Phytochemical analysis and evaluation of antioxidant potential of ethanol extract of *Allium cepa* and ultra-high homoeopathic dilutions available in the market: A comparative study. Indian Journal of research in homoeopathy 2017, 11(2): 88-96.
- [26] Oyewusi J.A., Saba A. B., Olukunle J. O. Phytochemical, elemental and acute toxic effects of methanol extract of onion (*Allium cepa*) bulbs in Wistar albino rats experimentally pre-exposed and rested for a week. Vom Journal of Veterinary Science 2015; 10 : 65-74.
- [27] Benkeblia N. Phenylalanine ammonia-lyase, peroxidase, pyruvic acid and total phenolics variations in onion bulbs during long-term storage. LWT-Food Science and Technology 2000; 33(2): 112-116.
- [28] Nuutila A.M., Puupponen-Pimiä R., Aarni M., Oksman-Caldentey K.M. Comparison of antioxidant activities of onion and garlic extracts by inhibition of lipid peroxidation and radical scavenging activity. Food chemistry 2003; 81(4): 485-493.
- [29] Aliyu A. B., Musa A. M., Oshanimi J. A., Ibrahim H. A., Oyewale A.O. Phytochemical analyses and mineral elements composition of some medicinal plants of Northern Nigeria. Nigerian Journal of Pharmaceutical Sciences 2008; 7(1):119-125.
- [30] Bajaj K.L., Kaur G., Singh J., Gill S.P.S. Chemical evaluation of some important varieties of onion (*Allium cepa* L.). Plant Foods for Human Nutrition 1980; 30:117-122.
- [31] Rodríguez-Bonilla P., Gandía-Herrero F., Matencio A., García-Carmona F., López-Nicolás J. M. Comparative study of the antioxidant capacity of four stilbenes using ORAC, ABTS+, and FRAP techniques. Food Analytical Methods 2017; 10: 2994-3000.
- [32] Miller H. E., Rigelhof F., Marquart L., Prakash A., Kanter M. Antioxidant content of whole grain breakfastcereals, fruits and vegetables. J. Am. Coll. Nut 2000; 19: 1-8.
- [33] Prakash D., Singh B. N., Upadhyay G. Antioxidant and free radical scavenging activities of phenols from onion (*Allium cepa*). Food chemistry 2007; 102(4): 1389-1393.

ETHNOBOTANICAL STUDY OF AN ASTERACEAE ARTEMISIA HERBA ALBA (ASSO.) IN CHOTT EL GHARBI (WESTERN ALGERIA)

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Abstract

The objective of this work is to identify the therapeutic uses of medicinal plants in the Chott El Gharbi region through ethnobotanical surveys carried out on a local population who have used phytotherapy for a long time in a way transmitted from generation to generation. The investigation was carried out in the two communes of Chott El Gharbi. Among the botanical families of the species most used in herbal therapy, Lamiaceae and Asteraceae. The best-known species in various treatments is Artemisia herba alba (Asso.). The leaves represent the most used parts of plants and the decoction represents the most frequent method of preparation.

Keywords: Artemisia herba alba (Asso.), Ethnobotanical surveys, medicinal plants, Chott El Gharbi, phytotherapy, Algeria

1. INTRODUCTION

Throughout the world, traditional medicine relies on the natural resources available in the local environment, as well as the knowledge and know-how of the local population. With an area of 2,381,741 km², Algeria is the largest river country in the Maghreb. It is known for its wide variety of medicinal and aromatic plants, as well as for the many common uses that each of the country's terroirs gives them. These are ancient know-how passed down from generation to generation, especially among rural populations. It is a medical heritage present among elderly women and healers [1]. The medicinal plants used are often available in the local environment, which facilitates the recognition and know-how necessary to exploit these resources [2]. Our region is characterized by a climate arid to semi-arid, characteristic of the Oran highlands, more precisely in the region of Chott El Gharbi, which is located in the northeast of the Wilaya of Naâma (Algeria).

2. METHODOLOGY

2.1. The study area

The Chott Gharbi Basin occupies an area of approximately 11.784 km² or approximately 1/3 of the Wilaya of Naâma.

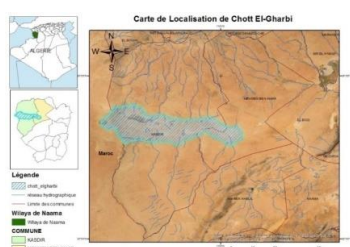


Figure 1. Map of study zone

It is bordered to the north by the mountains of Tlemcen (Djebel Sid Abed 1540 m and Mekaidou 1456 m altitude), to the east by the Moroccan mountains of Tendrara 1679 m and in the south by the mountains of Ksours (Djebels Gaaloul 1612 m and Guetoub El Hamara 1594 m). It is an endorheic basin which constitutes approximately 75.56% of Algeria and 24.46% of Morocco [3].

2.2. Bioclimatic and geomorphological presentation

Given the morphology of its relief, the Chott El Gharbi region presents a bioclimate of the semi-arid type in the north to arid in the south, with a cool to cold variant, and a relatively low average annual rainfall varying from 250 mm to less than 100 mm/ at South [4].

The north of the southern high plains of Oran is more watered compared to the south. Likewise, rainfall increases from west to east (longitudinal gradient: more than 300 mm per year at El Nâama [5]. The area figure 1, retained within the framework of this work, has the following main characteristics:

The region is classified as an area very sensitive to desertification because of the importance of climatic aridity, the unequal distribution of water, a high sensitivity of soils to desertification and constraints linked to the socio-economic situation of the populations (Overgrazing). *Artemisia herba alba* (Asso.) occupies large areas of the local steppe in the form of sagebrush rangelands. Often at the formation level with a clayey texture with the presence of limestone.

These rangelands experience significant anthropogenic pressure combined with episodic summer droughts of varying length in recent years [5].

2.3. Ethnobotanical surveys

At Chott El Gharbi in the Oran steppe, we carried out an ethnobotanical survey on the medicinal and aromatic plants used by the inhabitants of this region. Among the 39 species inventoried in the phytotherapeutic notebook of herbalists and healers in the region Table 1. All are spontaneous species.

The most widely used and distributed by the local population is *Artemisia herba alba* (Asso.) called also white mugwort. It is an endemic of the Mediterranean steppe and acquired a great advantage in the treatment of numbers of diseases [3].

Through the ethnobotanical investigation of spontaneous species from the western steppes of the Chott El Gharbi region of the wilaya of Naâma, we noted the following criteria to develop a biological profile of the species which will allow us to present its biological and phytochemical characteristics: biological type of Raunkiaer, therapeutic indications and traditional uses, chemical composition.

We have also listed, according to the availability of information, the active compounds of this plant and, then, its therapeutic indications and uses.

These criteria taken into account show on the one hand the active constituents of the species and its activities and on the other hand its biological type which justifies the adaptation of the species, its mode of multiplication and its biological conservation in a natural environment.

3. RESULTS AND DISCUSSIONS

The species encountered in the arid steppes mainly belong to biological types adapted to drought and harsh climatic conditions. These are therophytes and chamephytes which represent the highest levels of the biological spectrum of steppe vegetation. These biological types are very adapted to drastic aridity conditions [6]. *Artemisia herba-alba* (Asso.) is an herbaceous, perennial plant, greenish-silver in color, 30-50 cm in height with branched, rigid and erect stems figure 2.



Figure 2. *Artemisia herba alba* Asso. (Ozenda, 1991)

Table 1. Inventoried species in Chott El Gharbi

Species	Biological type	Morphological type
1. <i>Thymus algeriensis</i>	Ch	H.V
2. <i>Astragalus pentaglottis</i>	Th	H.V
3. <i>Muicaria prostrata</i>	Th	H.A
4. <i>Savia verbenacca</i>	He	H.A
5. <i>Plantago ovata</i>	He	H.A
6. <i>Brachypodium distachyum</i>	He	H.A
7. <i>Erucaria uncata</i>	Th	H.A
8. <i>Salsola foetida</i>	Th	H.A
9. <i>Atriplex halimus</i>	Ph	L.V
10. <i>Suaeda fruticosa</i>	Ch	L.V
11. <i>Arthrophytum scoparium</i>	Ch	H.V
12. <i>Lygeum spartum</i>	Ch	H.V
13. <i>Atriplex dimorphostegia</i>	Ch	H.A
14. <i>Salsola vermiculata</i>	Ch	H.A
15. <i>Malva aegyptiaca</i>	Th	H.A
16. <i>Ziziphus lotus</i>	Ph	L.V
17. <i>Salsola sieberi</i>	Ch	H.A
18. <i>Peganum harmala</i>	Th	H.V
19. <i>Plantago albicans</i>	Ch	H.V
20. <i>Hordeum murinum</i>	Th	H.A
21. <i>Pao bulbosa</i>	Th	H.A
22. <i>Stipa tenacissima</i>	Ch	H.V
23. <i>Pseudocytisus integrifolius</i>	Ch	L.V
24. <i>Artemisia herba-alba</i>	Ch	L.V
25. <i>Noaea mucronata</i>	Ch	L.V
26. <i>Alyssum scutigerum</i>	Th	H.A
27. <i>Arthrocnemum glaucum</i>	Ch	L.V
28. <i>Halogeton sativus</i>	Th	H.A
29. <i>Atractylis cancellata</i>	Ch	H.V
30. <i>Atractylis flava</i>	He	H.V
31. <i>Atractylis serratuloides</i>	He	L.V
32. <i>Helianthemum apertum</i>	He	L.V
33. <i>Helianthemum rubellum</i>	He	H.A
34. <i>Astragalus scorpiodes</i>	Th	H.V
35. <i>Herniaria hirsuta</i>	Th	H.A
36. <i>Schismus barbatus</i>	Th	H.A
37. <i>Cornulacac monocantha</i>	Ch	L.V
38. <i>Adonis dentata</i>	Th	H.A
39. <i>Fagonia arabica</i>	Ch	H.A

The leaves are small, sessile, pubescent and silvery in appearance [7]. Divided into thin, white, woolly strips. The flowers are grouped in clusters, with very small and ovoid flower heads of 1.5 to 3 mm in diameter, yellow to reddish in color (Bezza et al., 2010 [8]). The fruits are achenes. The plant's vegetative growth takes place in the fall (large leaves), then at the end of winter and in spring (smaller leaves) (Akrou, 2004 [9]).

Flowering begins in June and develops mainly at the end of summer [10]. The roots appear in the form of a main root, woody and thick, very distinct from the secondary roots and which sinks into the ground like a taproot. The root penetrates deeply to 40 to 50 cm and only branches at this depth [11].

The Asteraceae family, to which *A. herba alba* belongs, have been the subject of several phytochemical studies (Nassrallah et al., 2020 [12]). Many chemical studies have revealed that the aerial part of *Artemisia herba alba* as well as the genus *Artemisia* is rich in secondary metabolites such as polyphenols, flavonoids, lactones, tannins, essential oils [13-15]). Chemical investigations have shown that plants belonging to *A. herba alba* are rich in its quiterpene lactones such as eudesmanolides and germacranolides (Ayad 1989, Mssais et al., 2008 [16]). Artemisinin is the active medicinal substance Figure 3 isolated from the plant *Artemisia annua* and also present in *Artemisia herba alba* (Asso.) whose medicinal virtue has been known in China for more than 2,000 years. It is a sesquiterpene lactone carrying a peroxide group which seems to be the spearhead of its therapeutic effectiveness [17]. Artemisinin and its derivatives are essential components of artemisinin combination therapies (ACTs) used to treat millions of people with malaria. Artesunate, a derivative of artemisinin, is used to treat people with severe malaria [18]. The presentation below mainly focuses on *Artemisia annua* then *Artemisia afra*, because these are the *Artemisia* species for which the volume of information available is the greatest [19].

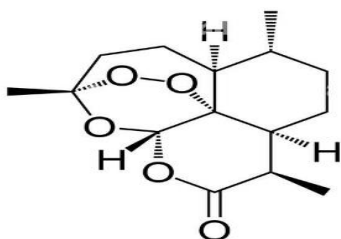


Figure 3. Chemical structure of Artemisinin

3.1. Therapeutic use

According to the ethnobotanical survey that we carried out, through a questionnaire which reached 1200 people belonging to the local population. On medicinal plants used in the therapy of diseases, the use of *Artemisia herba alba* dominates. According to a questionnaire, 46% of patients admit to having taken *Artemisia herba alba* for anti-flu treatments, 38% also used *Thymus* for various treatments, 6% were treated with *Atriplex halimus* and 2% for other species [19].

3.2. Methods of use and preparation

Regarding the method of use, observation of table 2 highlights the importance of the preparation methods (Decoction, Herbal Tea, Maceration, Infusion, etc.) compared to the others. Oral use appears to be a rule which responds to the mode of treatment of the most frequent pathologies and seems to be the most effective. Except for the treatment of skin and rheumatic conditions, the traditional therapist in the steppe region in general [20].

Table 2. Chemical characterization and mode of use of *Artemisia herba alba* (Asso.)

Species	Compounds	Therapeutic uses	Preparation
<i>Artemisia herba alba</i> (Asso.)	Terpenes Flavonoids	Hypoglycemic Hypolipidemic Anti-inflammatory Anti-parasitic Anti-microbial	Decoction Herbal tea Maceration Infusion

4. CONCLUSIONS

In Algerian steppe zones, populations mainly use traditional plant-based medicine, because it remains the most affordable, and recommended for its effectiveness (Boubekeur et al. [21]).

The investigation into herbal therapy at Chott El Gharbi presented in this work provided at first, preliminary information on the richness and diversity of spontaneous plants in these regions. In second, this investigation allowed us to select the species which has the strongest medicinal use among the steppe populations. *Artemisia herba alba* (Asso.) is species with strong medicinal utility alongside *Thymus algeriensis* and *Atriplex halimus*. Finally, due to their high demand among populations, these species should also be subject to conservation management [22].

5. REFERENCES

- [1] Ilbert, H., Hoxha, V., Sahi, L. Le marché des plantes aromatiques et médicinales: analyse des tendances du marché mondial et des stratégies économiques en Albanie et en Algérie 2016.
- [2] Sangare, M. M., Sina, H., Dougnon, J., Bayala, B., Atebo, J.M., Dramane, K. L. Etude ethnobotanique des plantes hépatotropes et de l'usage traditionnel de *Gomphrena celosioides* Mart. (Amaranthaceae) au Bénin. International Journal of Biological and Chemical Sciences 2012, 6(6), 5008-5021.
- [3] Yassine, B., Brahim, B. Apport de la teledetection et SIG dans l'identification des ressources en eau souterraines dans la région du Chott El Gharbi (wilaya de Naama) 2022.
- [4] Wael Z., Bouiadja B., Benslimane M., Mederbal K. L'écosystème steppique face à la desertification: Cas de la région d'El Bayadh, Algérie. VertigO. La revue en sciences de l'environnement 2009. Volume 9.
- [5] Ozenda P. Flore et végétation du Sahara (mise à jour et augmentée). Troisième Edition CNRS. Paris.
- [6] Aronson, J., Shmida, A. Plant species diversity along a Mediterranean-desert gradient and its correlation with interannual rainfall fluctuations. Journal of Arid Environments 1991, 23(3), 235-247.
- [7] Quezel P., Santa S. Nouvelle flore d'Algérie et des régions désertiques méridionales 1962. Tomes I et II, 1170.
- [8] Bezza L., Mannarino A., Fattarsi K., Mikail C., Abou L., Hadji Minaglou F. Chemical composition of the essential oil of *Artemisia herba-alba* issued from the district of Biskra (Algeria). Phytothérapie 2010. 8, 5, 277-281.
- [9] Akrouit A. Essential oil study of some pastoral plants from Matmata. Cah. Options. Med. 2004, 62, 289-292.

- [10] Djebaili S., Djellouli Y., Daget P. Les steppes pâturées des Hauts Plateaux algériens. Fourrages 1989. 120, 393-400.
- [11] Aidoud AE, Le Floc'h, HN, Le Houerou. Les steppes arides du nord de l'Afrique. RevSech, 2006. no.17(1-2): 19-30.
- [12] Nassrallah Y., Aouadj A., Khatir H. Impact of the exploitation of medicinal plants on biodiversity conservation in Saida and El Bayadh regions, Algeria. Biodiv. Res. Conservation 2020, 60, 11-22.
- [13] Kundan S., Anupam S. The Genus Artemisia: A Comprehensive, 2010.
- [14] Amor L. Etude de quelque prioritaire biochimique d'Artemisia herba Alba. Université de Farhat Aabas, Sétif. Thèse de majestère 2010, 242 p.
- [15] Al-Wahaibi LHN., Mahmood A., Khan M., Alkhatlan H.Z. Comparative study on the essential oils of Artemisia judaica and A. herba-alba from Saudi Arabia. Arabian Journal of Chemistry 2018, 11.
- [16] Ayad N., Djennane A., Ayache H., Hellal B. Contribution à l'étude de l'implantation de l'armoise blanche «Artemisia herba alba Asso» dans la steppe du sud de Tlemcen. Revue Ecologie- Environnement 2013,15, (2).
- [17] Messai L. Etude phytochimique d'une plante medicinale de l'Est algerien (Artemisia herba Alba).Thèse Doctorat: Chimie Organique. Constantine : université de Mentouri 2011,104 p.
- [18] Mohamed AH., El-Sayed M., Hegazy ME., Helaly S., Esmail A., Mohamed N.S. Chemical constituents and biological activities of Artemisia herba-alba. Records of Natural Products 2010, 4, (1).
- [19] O.M.S. Utilisation des formes non pharmaceutiques d'Artemisia. Organisation mondiale de la Santé. 2019.
- [20] Mounkaila S., Soukaradji B., Morou B., Karim S., Issoufou H.B.A., Mahamane A. Inventaire et gestion des plantes médicinales dans quatre localités du Niger. European scientific Journal 2017, 24 (13), 498-521.
- [21] Boukerker H., Salemkour N., Nouasria D., Benyakhlef B., Nacereddine .S, Chalabi Y .La végétation steppique au profit de la phytothérapie dans la région d'El Bayadh. Journal Algérien des Régions Arides (JARA) 2016, N°(13), 61-73
- [22] Ghezlaoui S., Benabadji N. La végétation des monts de Tlemcen (Algérie). Aspect phytoécologique. Botanica Complutensis 2018, (42), pp. 101-124.

EVALUATION OF MORPHOLOGICAL CHARACTERISTICS IN SOME APPLE VARIETIES (*MALUS PUMILA* MILL.) FROM NORTHEASTERN ALGERIA

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Abstract

The current investigation is centered on the characterization of specific apple cultivars in the Garza region, within the Teniet El Abed municipality, situated 55 km east of Batna (NE-Algeria). Utilizing descriptors outlined by UPOV 2015 pertaining to apples, the study focuses on morphological parameters of leaves, fruits, and terminal shoots across three varieties: Golden Delicious, Royal Gala, and Starkrimson. Additionally, soil analysis was conducted to ascertain its suitability for apple cultivation. The examination revealed limited morphological diversity among the investigated apple cultivars, with some descriptors, particularly those related to fruit traits, showing insignificant differences between cultivar types. Overall, the studied varieties - Golden Delicious, Royal Gala, and Starkrimson - exhibit distinct physiological and morphological characteristics. Variations in size, shape, skin color, flesh attributes, as well as sugar and acid content, contribute to the uniqueness of each variety. Whether one prefers sweet or tart apples, or favors larger or smaller fruits, there exists an apple variety to cater to individual tastes. Our findings complement molecular analyses and underscore the need for further exploration of apple germplasm, alongside sustained conservation efforts.

Keywords: apple, agronomy, conservation, orchard, fruit, genetic diversity

1. INTRODUCTION

The apple tree (*Malus pumila* Mill.) stands as the most cultivated fruit species globally, especially within the temperate zone (Houmani 1999 [1]; Chouinard et al. 2000 [2]). The apple ranks as the third most significant fruit crop worldwide, following citrus and banana, in terms of production volume. Its widespread cultivation across all continents, thriving under diverse environmental conditions, underscores its remarkable adaptability to varying ecological settings (Ercisli 2004 [3]; Gharghani et al. 2009 [4]; Radivojevic et al. 2014[5]). In Algeria, the cultivation of apples has experienced notable advancement, with cultivated areas expanding from 39,852 ha in 2010 to 40,553 ha by 2018. Concurrently, yields have demonstrated an upward trend, ranging from 72,233 kg/ha in 2010 to 171,635 kg/ha in 2020. Consequently, apple production has shown substantial growth, escalating from 378,637 tons in 2010 to 566,824 tons in 2020 (FAO 2022 [6]).

Nevertheless, the yields of 171,635 kg per hectare still lag behind European standards, such as those observed in France, which average 323,007 kg/ha (FAO 2022 [6]). This disparity appears to stem from various factors, notably inadequate mastery of cultivation techniques and suboptimal varietal adaptation. In the Aures region of eastern Algeria, apple cultivation serves as a significant socio-economic endeavor, particularly in Batna. The area dedicated to apple cultivation surpassed 4,380 ha in 2017, with a production reaching 900,000 quintals. This sector represents 19% of the total arboricultural area and is

concentrated in mountainous zones, specifically in the towns of Arris, Ichemoul, Teniet El Abed, and Marouana. The morphological characterization of *Malus* species has proven indispensable for providing thorough descriptions of germplasm collections, as well as informing breeding programs (Bozovic et al. 2015 [7]) and taxonomic studies (Hofer et al. 2014 [8]; Wagner et al, 2014 [9]). Genetic markers, particularly microsatellites, are favored over phenotyping due to their stability and cost-effectiveness in providing information (Reddy et al, 2002 [10]; Ban et al, 2014 [11]), the examination of agricultural germplasm through morphological traits remains relevant and valuable in diversity analysis (Bozovic et al. 2015 [7]; Kiraly et al. 2015 [12]; Kumar et al. 2018 [13]). Consequently, studies on apple morphological descriptions have been conducted in various regions including Bosnia and Herzegovina (Gasi et al. 2011 [14]), Canada (Watts et al. 2021 [15]), Hungary (Kiraly et al. 2015 [12]), India (Dolker et al. 2021 [16]), Iran (Farrokhi et al. 2013 [17]), Italy (Martinelli et al. 2008 [18]), the Kashmir Valley (Dar et al. 2015 [19]), Macedonia (Kiprijanovski et al. 2020 [20]), Montenegro (Bozovic et al. 2015 [7]), Serbia (Mratinic et al. 2012 [21]) and Turkey (Karatas, 2022 [22]), reporting high morphological diversity. The most frequently utilized morphological descriptors in these studies adhere to international guidelines such as IBPGR (1982 [23]) and UPOV (2005 [24]) with a primary focus on fruit characteristics. This emphasis on fruit traits aligns with the sensory characteristics and consumer preferences associated with apples (Pereira-Lorenzo et al, 2018 [25]).

This study primarily focuses on the agro-ecological and numerical characterization of specific varieties of apple trees (*Malus pumila* Mill.) within the Oued Abdi region, situated in the Garza area approximately 55 km southeast of Batna. It entails the examination of various morphological parameters of key organs, including annual shoots, flowers, leaves, and fruits. The objective is to analyze the distribution, homogeneity, and stability of the species, thereby contributing to future breeding programs in Algeria from both environmental and economic perspectives. Moreover, this research lays the groundwork for further agronomic and sensory studies aimed at enhancing the morphological description of apples. By providing valuable insights, it aims to advance our understanding of apple genetic resources.

2. MATERIALS AND METHODS

Soil analysis

Soil analysis was conducted in December, during the winter rest period, at four different depths. Commonly used analysis methods were employed for this purpose. The soil samples were analyzed at the regional laboratory of the National Institute of Soil, Irrigation, and Drainage (INSID) located in Oum El Bouaghi, eastern Algeria.

Plant material

The plant material utilized in this study comprises three varieties of apple trees - Golden Delicious, Royal Gala, and Starkrimson - grafted onto the MM 106 rootstock. These trees were planted in 2000 in Garza, situated 55 km southeast of Batna (NE-Algeria), at an altitude of 1600 m. A model orchard spanning one hectare was selected for the study, accommodating a total of 800 trees with varied planting distances. The planting arrangement includes a mixture of the three apple varieties.

For irrigation, a submersion system sourced from a well with an average depth of 40 m was employed. Fertilization was carried out using organic manure. The study focuses on a sample of 10 representative trees from each variety throughout the vegetative cycle. These specific references were chosen due to their widespread cultivation in Algeria.

Study methods

A comprehensive set of morphological descriptors, totaling 23, was evaluated for three organs: fruits, flowers, and shoots. These descriptors were sourced from UPOV (2015[26]). A total of 40 fruits and 40 flowers, along with 32 shoots per variety, were collected from various orientations within the tree crown for assessment.

Tree characterization

The tree characterization process encompassed the assessment of several key parameters, namely habitus (HAB), maturation time (MAT), and the length of terminal annual shoots (LTAS) categorized by orientation (E: east, W: west, N: north, S: south). This evaluation spanned from stage A of BAGIOLINI to stage A, signifying final fruit maturity. Throughout this period, the growth of terminal shoots originating from each variety's vegetative buds was meticulously tracked on a weekly

basis, considering their orientation until complete apex drop. Measurements of the length of terminal shoots were conducted using a digital caliper, with recorded results in millimeters (mm).

Flower characterization

The parameters studied for flower characterization include flowering period (FLOW), flower color (FLC), flower diameter (FLD), petal floral composition (PETF), floral stamen position relative to anthers (STPAN), as well as NPET (number of petals), NSEP (number of sepals), PETL (petal length), PETW (petal width), SEPL (sepal length), PISL (pistil length), NPIS (number of pistils), STAL (stamen length), and NSTA (number of stamens).

Fruit characterization

We have identified the following parameters for fruit characterization: fruit weight (WEIG), fruit length (LENG), fruit width (WIDT), fruit shape index (SHIN), fruit shape (SHAP), and fruit color (COLO), as outlined in Table 5. Fruit analyses were conducted on an average sample of 100 fruits per genotype, considering their orientation on the tree. Fruit weight (WEIG) was determined using an analytical balance of "type: Metler 1200," with results expressed in grams with a precision of 0.01 g. Fruit length (LENG) and fruit width (WIDT) were measured using digital calipers. The fruit shape index (SHIN) was calculated using the formula $SHIN = \text{length} / \text{width}$.

To determine the significance of the differences among the varieties concerning the studied tree and fruit characteristics, an analysis of variance (ANOVA) was conducted, followed by the application of the Tukeys (0.05%) test using SAS 2000 V. 9.0 software.

3. RESULTS AND DISCUSSION

Soil characterization

The results of physico-chemical analyses are depicted in tables 1 and 2. The soil type identified exhibits variable texture with depth, generally categorized as clay-sandy. This presence of fine elements suggests a potential risk of root asphyxiation, particularly when these particles become saturated with water, especially during periods of heavy rainfall or intensive irrigation. Given the fine structure of this soil type, there is an anticipated risk of compaction due to poor permeability. Clay-sandy-loamy soils are typically considered most conducive for fruit tree cultivation (Benaziza et al. 2007 [27]). The optimal organic matter content typically ranges from 3 to 4%. For the species under consideration, a humus content between 1.5 to 3% is deemed satisfactory. In our case, the total soil calcium content is classified as very low, measuring less than 2%. Typically, calcium levels ranging from 2 to 10% are considered low, while levels exceeding 25% are regarded as very high.

The results indicate that the pH of the analyzed soils ranges from neutral to alkaline, specifically between 7.15 and 7.39, posing no risks for cultivation (Table 2). In the case of alkaline soil, the addition of organic matter and

nitrogen can help buffer the pH and enhance tree nutrition and growth. A recommended application rate is five kilograms of sheep manure and 500 grams of urea (46% nitrogen). Soil salinity levels are interpreted based on the standards established by Aubert (1978 [48]). According to these standards, the studied soil is not considered salty, with salinity levels falling between 0.43 and 0.48.

Table 1. Physical analysis results of soil in the studied orchard

Elements	Soil Depth (cm)			
	00-20	20-40	40-60	60-80
Granulometry	International Method (Sieving and Sedimentation) (International Standard ISO 11277)			
Clay	40.06	36.71	37.40	45.22
Fine Sand	03.86	17.70	19.09	11.61
Coarse Sand	16.92	08.19	08.73	10.01
Fine Silt	21.56	19.04	17.38	18.16
Coarse Silt	17.60	18.39	17.41	14.81
Total Silt	20.78	25.89	27.82	21.62
Total Sand	39.16	37.43	34.79	32.97
Texture	Clayey-sandy			

Table 2. Soil chemical analysis in the studied orchard

Depth	pH	EC (dS/m)	Lim (%)	OM (%)
00-20 cm	7.15	0.48	1.47	3.71
20-40 cm	7.27	0.45	0.74	3.39
40-60 cm	7.32	0.48	0.74	1.17
60-80 cm	7.39	0.43	0.00	1.69
EC: Electrical Conductivity; Lim: limestone; OM: organic material				

Characterization of Trees and Annual Shoots

The habitus for the tree of each variety is spread out, no noticeable difference between them. The analysis of the results revealed no considerable differences between cultivars for their phenological behavior. The three genotypes started their vegetative activity in April; however, the vegetative growth was marked from spring to autumn without any summer pause (Table 3).

Table 3. The growth habit of apple trees and the length of annual shoots. Means with the same letters are not significantly different at $p < 0.05$ (Tukey Test).

Traits (mm)	Golden Delicious	Royal Gala	Starkrimson
HAB	Spread	Spread	Spread
LTAS-N	652.87 ^A	474.61 ^B	325.03 ^C
LTAS-S	401.37 ^A	345.94 ^B	277.53 ^C
LTAS-E	645.59 ^A	447.49 ^B	390.91 ^C
LTAS-W	411.11 ^A	384.19 ^B	215.46 ^C
HAB: Habitus; LTAS: Length of terminal annual shoots; N: North; S: South; E: East; W: West			

The length of annual shoots exhibits significant and variable impacts based on the considered variety. The orientation factor plays a crucial role in determining orchard cultivation practices, particularly regarding light exposure. Average final lengths range from 21.55 cm (Starkrimson) to 65.29 cm (Golden Delicious). The 'Golden Delicious' cultivar displayed the longest shoots, measuring at 92.42 cm, while the 'Royal Gala' variety exhibited the shortest, at 2.20 cm.

For 'Golden Delicious' and 'Royal Gala', shoots facing North demonstrated the highest growth rates, followed by those facing East, West, and South respectively. Conversely, in the case of the Starkrimson variety, shoots oriented towards the East displayed the highest growth rates, succeeded by North-facing shoots, South-facing shoots, and finally West-facing shoots.



Figure 1. Trees of apple *Malus pumila* at flowering and fruiting period for the three studied varieties from Garza (NE-Algeria)

Table 4. Flower characteristics of the three apple varieties. Means with the same letters are not significantly different at $p < 0.05$ (Tukey Test).

Traits (mm)	Golden Delicious	Royal Gala	Starkrimson	P
FLOW	Early May	End-April	Early May	--
FLC	Pale pink	Pale pink	Pale pink	--
DFL	Medium	Medium	Medium	--
PETF	Overlap.	Overlap.	Overlap.	--
STPAN	Below	Below	Below	--
NPET	5 ^A	5 ^A	5 ^A	NS
NSEP	5 ^A	5 ^A	5 ^A	NS
PETL	2,26±0,10 ^A	2,34±0,11 ^A	2,29±0,27 ^A	0.565
PETW	1,61±0,09 ^A	1,48±0,07 ^B	1,68±0,16 ^A	0.002
SEPL	0,77±0,13 ^A	0,81±0,12 ^A	0,85±0,07 ^A	0.268
PISL	1,04±0,10 ^A	0,97±0,09 ^A	0,83±0,07 ^B	<0.001
NPIS	5 ^A	5 ^A	5 ^A	NS
STAL	0,85±0,09 ^A	0,90±0,06 ^A	0,87±0,06 ^A	0.343
NSTA	19-20 ^A	18-20 ^A	19-20 ^A	0.087
FLOW: flowering time; FLC: flower color; DFL: diameter of the flower; PETF: petal floral composition; STPAN: stamen position relative to the anthers; NPET: number of petals; NSEP: number of sepals; PETL: petal length; PETW: petal width; SEPL: sepal length; PISL: pistil length; NPIS: number of pistils; STAL: stamen length; NSTA: number of stamens				

There was a minor variation observed among the species in terms of flowering time, categorized as medium and late (Table 4). Royal Gala trees typically flower towards the end of April, while the remaining two varieties initiate flowering during the first week of May. Across the same variety, the flowering duration spans from 10 to 15 days. The different apple varieties exhibit maturity throughout the year (Bretaudié and Fauré 1991 [29]; Boré and Fleckinger 1997 [30]).

There is no risk of frost affecting the flowers. However, in regions where frost during flowering is a possibility due to altitude, it may be advisable to opt for varieties that flower later in the season (Šebek 2011 [31]).

Typically, the color of apple flowers is white, pink, or red (Mišić 2002 [32]). The flowers of the varieties examined in this study predominantly exhibited a pale pink hue and were of moderate size. The position of the stigmas relative to the anthers was above.

The results presented in Table 4 indicate slight variations in the length and width of the sepals, petals, pistils, and stamens among the three varieties. However, for the majority of the parameters measured, all three varieties are grouped together. Two exceptions were noted: the average petal width for the Royal Gala variety was slightly lower (1.48 mm) compared to Golden Delicious and Starkrimson (1.61 mm and 1.68 mm, respectively), and the average pistil length for the Starkrimson variety was slightly lower (0.83 mm) than the other two varieties. No differences were observed in the number of each flower component across all varieties.

Characterization of fruits

The quality of the fruit is defined by the degree of excellence or superiority in terms of sensory properties, nutritional values, mechanical properties, and functional properties. In the case of apples, the most influential quality indicators are the external indicators (skin color, size) and internal indicators (texture, taste, aroma), based on consumer preference studies (Kühn & Thybo, 2001 [33]; Pathare, Opara & Al-SAID, 2013 [34]).

Table 5. Characteristics of Fruits. Means with the same letters are not significantly different at $p < 0.05$ (Tukey Test).

Traits (mm)	Golden Delicious	Royal Gala	Starkrimson	P
WEIG	129,74 ±14,56 ^B	138,20 ±19,86 ^A	140,32 ±17,75 ^A	<0.001
LENG	63,81 ±3,84 ^A	62,45 ±5,83 ^B	59,47 ±3,72 ^C	<0.001
WIDT	67,91 ±3,74 ^C	71,86 ±5,84 ^A	70,04 ±4,06 ^B	<0.001
SHIN	0.94 ^A	0.87 ^B	0.85 ^B	<0.001
SHAP	Oval	Circular	Conical Strangled	/
COLO	Yellow	Orange-Red	Red-Purple	/
MAT	Middle of October	Middle of September	End of October	/

WEIG: weight; LENG: length; WIDT: width; SHIN: shape index; SHAP: shape; COLO: color; MAT: Maturity time

The studied varieties exhibit yellow, orange-red, and red-purple colors. The fruit of "Golden Delicious" features a surface that is 100% yellow, while "Royal Gala" displays an orange-red color, and "Starkrimson" showcases a red-purple hue, according to UPOV standards (2015 [26]). The background color of the apple is linked to its ripeness. The reduction in green coloring intensity occurs due to the breakdown of chlorophyll, leading to a yellowing of the skin (Grierson and Kader, 1986 [35]).

The flesh (mesocarp) color of all three varieties is white, consistent with the findings of Tomić et al. (2011 [36]). Additionally, alongside white, cream and greenish hues are also observed in the flesh.

The weight, length, width, shape index, and shape of the fruit are detailed in Table 5. Apple varieties exhibited a wide range of fruit weights, spanning from 98g to 224g. The Tukey test revealed a significant difference between the varieties concerning fruit weight. "Royal Gala" and "Starkrimson" varieties were classified in the first group, displaying higher weights, whereas the first variety "Golden Delicious" was placed in the second group, featuring the lightest fruits.

In comparison to other studies, Ozrenk et al. (2011 [37]) investigated local apple varieties of Eastern Anatolia in Turkey, revealing a variation in fruit weight ranging from 20.9 to 139.3 g. Similarly, Mratinić and Fotirić-Akšić (2012 [21]) conducted research in southern Serbia, reporting fruit weights between 70 and 193.33 g. The majority of fruits fell within the weight range of 100 to 200 g, consistent with findings from studies by Mratinić and Fotirić-Akšić (2011 [38]), Tomić et al. (2011 [36]), and Šebek (2013 [39]).

The length of the fruits ranged from 51.62 to 81.47 mm, while the width varied between 59.35 and 89.70 mm. Comparing our data with other authors, such as Zovko et al. (2010 [40]), Šebek (2011 [31]), and Tomić et al. (2011 [36]), it can be concluded that the dimensions of the fruits fall within a similar range. This suggests that fruits with similar weights tend to have similar dimensions, indicating a correlation between these characteristics. The coefficient of variation (CV) for fruit weight was found to be 3.36%, indicating that fruit weight is the least variable property. This is attributed to the fact that fruit weight is more influenced by environmental factors compared to dimensions (Šebek 2011 [31]). The coefficient of variation (CV) is 2.93% for fruit length and 2.31% for fruit width.

The lowest fruit shape index of 0.75 was observed in "Starkrimson," while the fruits of "Golden Delicious" with a shape index of 1.04 were the longest.

Considering the fruit ripening period, the first selection would be 'Royal Gala,' as its fruits ripen in September. 'Golden Delicious' and 'Starkrimson' are the latest ripening cultivars, with fruits ripening in October.

The shape of the fruit varied among selections, with oval, circular, and conical constricted fruits all observed among the apple trees.

The significance of studying these characteristics was highlighted by Mulas and Cani (1999 [41]), who noted a significant correlation between fruit weight and volume, as well as between fruit weight and seed weight per fruit. Characterizing new cultivars enhances our understanding of the properties and variability of the species, thereby providing initial insights into potential uses of different cultivars. For instance, the color and shape of the berries are valuable in selecting ornamental cultivars, while the correlation between shoot length and the number of nodes is crucial for fruit yield.

4. CONCLUSIONS

The three cultivated apple tree varieties exhibited significant variation across most of the parameters examined. Distinctions were evident in terms of vegetative growth of annual shoots, fruit weight, and color, while variations in floral and fruiting dimensions were less pronounced. This diversity holds significant implications for the sustainable development and consumption of apples. Given the microclimate of the region, these cultivated varieties present compelling prospects for further development and preservation. Commercial and agronomic attributes carry substantial weight and warrant detailed evaluation, serving as invaluable information for future selection and dissemination programs. This characterization relies heavily on quantitative traits, which can be challenging to measure and at times subjective. Establishing rigorous protocols is imperative to ensure the reliability and repeatability of observations, utilizing measurable and more precise characteristics.

Although this study is limited in scope, conducted on a restricted number of varieties, its repetition and expansion, particularly across additional criteria such as flowers, fruits, and shoots, would enhance its reliability and decisiveness. Supplementing morphological characterization with molecular analysis to pinpoint agronomically important genes, map each variety, and obtain its genetic fingerprint would greatly enhance local and national-level cultivation efforts.

5. REFERENCES

- [1] Houmani, M. Projet de conversion, Ed. I.N.R.A- EL-Harrach, Alger 1999 ; 15.
- [2] Chouinard, G., Firlé, J.A., Vanoosthuyse, F. and Vincent, C. Guide d'identification des ravageurs des pommiers et leurs ennemis naturels. IRDA et Saint- Laurent. Québec 2000; 69.
- [3] Ercisli, S. A short review of the fruit germplasm resources of Turkey. Genetic Resources and Crop Evolution 2004; 51:419-435.
- [4] Gharghani, A., Zamani, Z., Talaie, A., Oraguzie, N.C., Fetahi, R., Hajnajari, H., Wiedow, C. and Gardiner, S.E. Genetic identity and relationships of Iranian apple (*Malus domestica* Borkh.) cultivars and landraces, wild *Malus* species and representative old apple cultivars based on simple sequence repeat (SSR) marker analysis. Genetic Resources and Crop Evolution 2009; 56:829-842.
- [5] Radivojevic, D.D. Milivojevic, J.M., Oparnica, C.D.J. and Vulic, T.B. Djordjevic, B.S. and Ercisli, S. Impact of early cropping on vegetative development, productivity, and fruit quality of Gala and Braeburn apple trees. Turkish Journal of Agriculture and Forestry 2014; 38(6):773-780.
- [6] F.A.O. Production agricole, cultures primaires, Banque de données statistiques. F.A.O. <https://www.fao.org/home/fr> 2022.
- [7] Bozovic, D., Lazovic, B., Ercisli, S., Adakalic, M. and Jacimovic, V. Morphological characterization of autochthonous apple genetic resources in Montenegro. Erwerbs-Obstbau 2015; 58(2), 93-102.
- [8] Hofer, M., Mohamed, M. A., Eldin, S., Sellmann, J. and Peil, A. Phenotypic evaluation and characterization of a collection of *Malus* species. Genetic Resources and Crop Evolution 2014; 61(5), 943-964.
- [9] Wagner, I., Maurer, W. D., Lemmer, P., Schmitt, H. P., and Wagner, M. Hybridization and Genetic Diversity in Wild Apple (*Malus sylvestris* (L.) Mill.) from Various Regions in Germany and from Luxembourg. Silvae Genetica 2014; 63(3):81-94.
- [10] Reddy, M. P., Sarla, N., and Siddiq, E. A. Inter Simple Sequence Repeat (ISSR) polymorphism and its application in plant breeding. Euphytica 2002; 128(1): 9-17.
- [11] Ban, S.H., Yun, W.H., Kim, G.H., Kwon, S.I. and Choi, C. Genetic identification of apple cultivars bred in Korea using simple sequence repeat markers. Horticulture Environment and Biotechnology 2014; 55(6), 531-539.
- [12] Kiraly, I., Ladanyi, M., Nagyistvan, O. and Toth, M. Assessment of diversity in a Hungarian apple gene bank using morphological markers. Organic Agriculture 2015; 5:143-151.
- [13] Kumar, C., Singh, S.K., Pramanick, K.K., Verma, M.K. and Srivastav, M. Morphological and biochemical diversity among the *Malus* species including indigenous Himalayan wild apples. Scientia Horticulturae 2018; 233:204-219.
- [14] Gasi, F., Simon, S., Pojskic, N., Kurtovic, M. and Pejic, I. Analysis of morphological variability in Bosnia and Herzegovina's autochthonous apple germplasm. Journal of Food, Agriculture and Environment 2011; 9(3-4):444-448.
- [15] Watts, S., Migicovsky, Z., and McClure, K.A. Quantifying apple diversity: A phenomic characterization of Canada's Apple Biodiversity Collection. Plants, People, Planet 2021; 3.
- [16] Dolker, T., Kumar, D., Chandel, J.S., Angmo, S. and Chaurasia, O.P. Phenological and pomological characteristics of native apple (*Malus domestica* Borkh.) cultivars of trans-himalayan ladakh. India. Defence Life Science Journal 2021; 6:64-69.
- [17] Farrokhi, J., Darvishzadeh, R., Maleki, H. and Naseri, H. Evaluation of Iranian native apple (*Malus domestica* Borkh.) germplasm using biochemical and morphological characteristics. Agriculturae Conspectus Scientificus 2013; 78(4):307-313.
- [18] Martinelli, F., Busconi, M., Camangi, F., Fogher, C., Stefani, A. Ancient pomeoideae (*Malus domestica* Borkh. and *Pyrus communis* L.) cultivars in appennino toscano. Caryologia 2008; 61(3):320-331.
- [19] Dar, J.A., Wani, A.A. and Dhar, M.K. Morphological, biochemical, and male-meiotic characterization of apple (*Malus domestica* Borkh.) germplasm of Kashmir Valley. Chromosome Botany 2015; 10(2): 39-49.
- [20] Kiprijanovski, M., Arsov, T. and Saraginovski, N. Pomological, quality, and organoleptic traits of some autochthonous apple cultivars in Prespa region, North Macedonia. Acta Horticulturae 2020; 1289:35-42.
- [21] Mratinić, E. and Fotirić-Akšić, M. Phenotypic diversity of apple (*Malus* sp.) germplasm through the principal component analysis. Genetika 2012; 43(2):331-340.
- [22] Karatas, N. Morphological, sensory, and biochemical characteristics of summer apple genotypes. Brazilian Journal of Biology 2022; 82:1-10.
- [23] IBPGR. Descriptors list for apple (*Malus*), ed. R, W. and RA, S. (International Board for Plant Genetic Resources (IBPGR); Commission of the European Communities (CEC)) 1982.
- [24] UPOV. Apple (*Malus domestica* Borkh.). Guidelines for the conduct of tests for distinctness, uniformity, and stability. International Union for the Protection of New Varieties of Plants (UPOV). Geneva 2005; 25-25.
- [25] Pereira-Lorenzo, S., Fischer, M., Ramos-Cabrera, A.M. and Castro, I. Apple (*Malus* sp.) Breeding: Present and Future.

- In Advances in Plant Breeding Strategies: Fruits, ed. J, E. A.-K., SM, J., and V., J. D. (*Springer International Publishing*) 2018; 3-29.
- [26] UPOV. Principes directeurs pour la conduite de l'examen de la Distinction, de l'homogénéité et de la stabilité 2015; 38p.
- [27] Benaziza, A., Lebid, H. Characterization of some varieties of apricot (*Prunus armeniaca* L.) in the region of M'chouneche wilaya of Biskra 2007; 103p.
- [28] Aubert, G. Soil analysis methods. Ed : CNDP. CRDP Marseille 1978.
- [29] Bretaudeau, J. and Fauré, Y. Couverture de l'ouvrage Atlas d'arboriculture Fruitière 1991 ; 232 p.
- [30] Bore, J.M., Fleckinger. Pommiers à cidre_variétés de France. Paris 1997.
- [31] Šebek, G. Organic fruit production. Austrian Development Agency, Austria (LMUC project) 2011.
- [32] Mišić, P. Special breeding of fruit trees. Institute for research in agriculture 'Serbia' and Partenon 2002.
- [33] Kühn, B.F. and Thybo, A.K. The influence of sensory and physiochemical quality on Danish children's preferences for apples. *Food Quality and Preference* 2001; 12(8):543-550.
- [34] Pathare, P.B., Opara, U.L. and Al-Said, F.A.J. Colour measurement and analysis in fresh and processed foods: A review. *Food and Bioprocess Technology* 2013; 6(1): 36-60.
- [35] Grierson, D., Kader, A. Fruit ripening and quality. In: *The Tomato Crop: A Scientific Basis for Improvement* (ed.J.G. Atherton & J. Rudich). Chapman & Hall, London, UK 1986.
- [36] Tomić, L., Ninić, P. and Cvetković, M. The study of the properties of fruit of autochthonous apple varieties in Western Bosnia. *Proceedings of XVI Conference on biotechnology with international participation, Čačak* 2011; 16(18): 353-358.
- [37] Ozrenk, K., Gundogdu, M., Kaya, T. and Kan, T. Pomological properties of local apple cultivars grown in Çatak and Tatvan districts. *Journal of Agricultural Sciences* 2011; 21(1):57-63.
- [38] Mratinić, E. and Fotirić-Akšić, M. Evaluation of phenotypic diversity of apple (*Malus sp.*) germplasm in south Serbia. *Brazilian Archives of Biology and Technology* 2011; 55(3):349-358.
- [39] Šebek, G. Autochthonous cultivars of apple from the area of the upper Polimlje. *Agric* 2013; For 59(2):67–74.
- [40] Zovko, M., Vego, D. and Zovko, M. Pomological properties of autochthonous cultivars in the area Žepča. *Glasnik Zastite Bilja* 2010; 1:54-74.
- [41] Mulas, M., Cani, M.R. Germplasm evaluation of spontaneous myrtle (*Myrtus communis* L.) for cultivar selection and crop development. *Journal of Herbs Spices and Medical Plants* 2022; 6(3): 31-49.

FACTORS INFLUENCING MILK YIELD DURING LACTATION OF D'MAN EWES IN ITS CRADLE IN ALGERIA

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Abstract

A study was conducted at the National Institute of Agricultural Research (Adrar station) between 2017 and 2019 to assess the milk yield potential of prolific D'man ewes. A total of 210 daily milk production records from (of) 21 D'man ewes were collected during three successive lambings with the weighing method before and after feeding followed by manual milking. In addition, the effects of birth type, lambing rank, birth season and weight of ewes to the struggle (at breeding) on milk production were analyzed. The least-squares averages of daily and total milk production of D'man ewes were 0.85 ± 0.03 kg and 59.1 ± 0.96 kg, respectively, and the highest daily milk yield was observed in the second week of lactation. Ewes suckling more than two lambs had the highest milk yield. Indeed, ewes with triplets or more (+57.3%) and twins (+22.1%) have a significantly higher milk yield ($P < 0.01$) than ewes nursing single lambs. The effect of the other factors was not significant on milk production of D'man ewes. It can be concluded that increasing the quantity of milk produced per ewe according to the number of lambs suckled will help to make the most of multiple lambings thanks to a low mortality rate and improved growth, especially during the first month of lactation.

Keywords: D'man ewes, lactation curve, milk yield, oases, prolificacy

1. INTRODUCTION

Sheep breeding constitutes an activity adapted to practically all agroecological zones of Algeria. Its total headcount is around 22 million heads (MADR 2023 [1]). The importance of this breeding in Algeria lies in the richness of its genetic resources.

Currently, this herd consists of at least 9 breeds presenting various characteristics of resistance, prolificacy, productivity as well as good adaptability in arid environments; steppe and Saharan (Djaout et al. 2017 [2]). The D'man is the local breed of the oases of southern Morocco and southwestern Algeria, it is exploited in the palm groves of Touat, Tidikelt and Gourara (Foley and Meslin 1924 [3]; Bouix and Kadiri 1975 [4]).

This breed has considerable adaptability to Saharan conditions (Chellig 1992 [5]). The D'man ewe has an average adult body weight of 33.6 kg (Boubekour et al. 2015 [6]), and is renowned for its interesting reproduction performance, including its high prolificacy with an average of 190% and the possibility of its exploitation in an accelerated lambing system (Boubekour et al. 2019 [7]). It is a non-seasonal breed, the ewe can accept the male all year round (Derqaoui 2003 [8]).

This remarkable numerical productivity requires a good knowledge of the quantity of milk supplied by the ewe to its lambs insofar as it makes it possible to provide lactating ewes with a food ration according to their production needs and to carry out a selection of ewes by elimination of mothers who do not feed their lambs sufficiently.

With this in mind, the study aims to provide more information on the milk yield of D'man ewes reared in the oases production system in the region of Adrar and to determine the main factors that influence this production, using the double weighing method and manual milking.

2. MATERIALS AND METHODS

The study was carried out at the experimental station of the National Institute of Agronomic Research in Adrar in the southwest of Algeria. The station is located approximately 5 km southwest of the capital of the wilaya of Adrar at latitude $27^{\circ} 49' N$ and longitude $00^{\circ} 11' E$, and an altitude of 279 m above sea level. It is located in the hyperarid bioclimatic stage with negligible rainfall of less than 25 mm per year. The average temperature fluctuates between $0^{\circ}C$ in winter to more than $45^{\circ}C$ in summer.

Animal conduct

A total of 210 daily milk production records of 21 D'man ewes were collected during 3 successive lambings (autumn 2017, summer 2018 and spring 2019).

These females were on average 30 months old and have an average weight of 36 kg and were on their 1st, 2nd, 3rd or 4th lambing (Figure 1). The ewes were farmed in an accelerated lambing system with three farrowings every 24 months and were constantly kept in permanent housing.

The feeding behavior of the animals was adapted to the Oasian breeding system, which is based on the

valorization of the by-products of the palm grove (Boubekeur & Benyoucef 2014 [9]).

The ewes received a daily ration based on the number of lambs suckled (Table 1). For the lambs, the diet was exclusively milk during the first month. From the 2nd month, they received, ad libitum, a mixture of concentrate composed of barley, bran, dates and vitamin-mineral supplement. Weaning was done at 70 days of age. At all times, local salt stones and water were provided to the animals.

Table 1. Feed rations for ewes D'man based on breastfed lambs (in kg/animal/day)

Ration distributed		Breastfeeding type		
		Simple	Double	Multiple
Coarse foods	Alfalfa (autumn)	02	02	02
	Oats (spring)	02	02	02
	Millet (Summer)	02	02	02
	Crushed palm fronds	0,25	0,25	0,25
Concentrate foods	Barley	0,50	0,60	0,70
	Wheat bran	0,20	0,25	0,30
	Crushed dates	0,20	0,30	0,40
	vitamin-mineral supplement	0,10	0,10	0,10

the advantage of determining the quantity of milk naturally available to lamb (Boujenane et al 1996 [12]). Milk recording was carried out once a week over a period of 70 days, with the first taking place 3 to 7 days after lambing. The day before the check-up day (5 p.m.), the babies are separated from their mothers.

The next day, at 8 a.m., a first milk check using the weighing method before and after feeding the lambs, supplemented by manual milking.

After the first check, the lambs remain separated from their mothers and a second check was carried out on the same day at 5 p.m. Daily milk production is determined by the sum of the quantities of milk fed and milked during successive morning and evening checks (Figure 2).



Figure 1. Ewes of the breed D'man

Controls carried out

To estimate the milk production of ewes, the method chosen was the weighing of lambs before and after feeding described by Ricordeau et al. 1960 [10], because it gives a precise idea of the quantity of milk consumed by the lambs (Ünal et al 2007 [11]). This method also has



Figure 2. Method of weighing before and after feeding

The total quantities of milk produced were estimated using the Fleishmann method (Boujenane et al 1996 [12]). The average of the estimation of two successive controls (C_i and C_{i+1}) was considered characteristic of the interval separating the two controls and the milk production per interval was obtained by the following formula:

$$[(C_i + C_{i+1})/2] \times 7 \text{ (days)} \quad (1)$$

C_i is the estimated milk production from the previous control and C_{i+1} is the next control milk quantity.

Milk production at the first control was calculated by multiplying the quantity of milk obtained during this control by the number of days separating lambing from the first control. The persistence coefficient (milk production of the n^{th} week/milk production of $(n-1)^{\text{th}}$ week, from the week of appearance of the maximum production) was calculated.

The variables studied were the average daily milk production (DMP) and weekly milk production from the 1st to the 10th week in kg per day and per week respectively, the milk production of the 1st (MPM1) and 2nd month (MPM 2) of lactation in kg per month, as well as the total milk production (TMP) obtained during the 70 days of lactation.

Statistical analysis

All statistical analyses were carried out using SPSS/PASW 20 statistical software. Descriptive statistics for the variables studied were calculated and the means were presented with their Standard Errors (mean $\pm$ SE). An analysis of variance of fixed effects includes the effect of lambing season; the effect of lambing rank (parity), the effect of ewe weight and the effect of the number of lambs suckled per ewe was made by univariate analysis of the general linear model of SPSS (Table 2). The statistical difference was reported at $p < 0.05$.

Table 2. Modalities of the factors tested in the analysis of variance for milk control

Factor tested	Level	modality	Number	Percentage
Lambing season	1	Autumn	11	27,5
	2	Summer	12	30,0
	3	Spring	17	42,5
lambing rank (parity)	1	primiparous	13	32,5
	2	2 nd lambing	15	37,5
	3	Multiparous (3 and more)	12	30,0
Weight of the ewe in wrestling	1	Weight $\leq$ 33 kg	17	42,5
	2	33 < weight $\leq$ 40 kg	15	37,5
	3	Weight > 40 kg	08	20,0
Number of lambs suckled	1	A single lamb	19	47,5
	2	Two lambs	18	45,0
	3	Three lambs and more	03	7,50

3. RESULTS AND DISCUSSION

Quantities of milk produced

The levels of average milk production of D'man ewes quantified per day, per week, at one month (28 days), at two months (56 days) and total production at 70 days, according to the method weighed before and after suckling of lambs, are presented in Table 3. The D'man ewes achieved an average daily production of 0.85 ± 0.03 kg per day with values ranging from 0.50 to 1.24 kg per day. Thus, the total milk production achieved after 10 weeks of lactation in this study was 59.1 ± 1.96 kg. The coefficients of variation were large with values above 20%, indicating a wide dispersion of values around the mean. Of these, D'man ewes produced an average of 26.5 kg and 23.8 kg in the first and second month of lactation, respectively.

The total milk production (TMP) achieved by D'man ewes was significantly lower than the values reported by Boujenane and Lairini (1992) [13] of 78 kg over 10 weeks of lactation and by Boujenane and Kerfal (1992) [14] who reported a total of 81.2 kg after 12 weeks of lactation in the same breed in Morocco. However, this average total milk production was higher than previous reports in some prolific breeds by 63.5 and 48.4 kg in ewes Avishaan and GMM (Garole x Malpura) respectively after 90 days of lactation Prakash et al. (2019) [15] and 43.6 kg in Priangan ewes (Tiesnamurti et al. 2012 [16]). This difference compared to prolific breeds may be related to the driving conditions of the animals, the average age and weight of the sample studied, and the duration of milk recording in each study.

However, among local Algerian breeds, the total milk production obtained was slightly higher compared to the average estimated in Rembi ewes (55.3 kg) at 112 days of lactation, according to Benchohra et al. (2014a) [17] and the total obtained by Benyoucef and Ayachi (1991) [18] of 56 kg in Hamra ewes during 42 days of lactation by the hormonal method (oxytocin). Likewise, the milk production of the 1st month estimated in this study (26.5 kg) was very low compared to the value given by Belkheir et al. (2021) [19] in the Tazegzawt breed (31.6 kg) but higher than the average estimated by Benchohra et al. (2014b) [20] in the Rembi breed, with milk production of 21.5 kg after 28 days of lactation.

Table 3. Average milk production ($\pm$ SE) daily, weekly, monthly and total of D'man ewes (kg)

Variables	Mean $\pm$ SE	Minimum	Maximum
MP daily	0.85 ± 0.03	0,50	1,24
MP week 1	1.00 ± 0.05	0,53	1,74
MP week 2	1.06 ± 0.04	0,66	1,70
MP week 3	0.98 ± 0.04	0,51	1,56
MP week 4	0.96 ± 0.03	0,41	1,37
MP week 5	0.93 ± 0.04	0,38	1,45
MP week 6	0.86 ± 0.04	0,33	1,54

MP week 7	0,79 ± 0,04	0,37	1,61
MP week 8	0,69 ± 0,03	0,30	1,14
MP week 9	0,63 ± 0,03	0,21	1,02
MP week 10	0,59 ± 0,03	0,28	0,97
MP 1 st month	26,5 ± 0,92	16,3	38,3
MP 2 nd month	23,8 ± 0,88	13,8	37,7
MP total	59,1 ± 1,96	35,3	87,9

MP : Milk production

Lactation curve

The initial mean milk production of D'man ewes was 1.00 kg/d and reached a maximum value of 1.06 kg in the 2nd week, then it decreased to 0.59 kg in the 10th week of lactation (Table 3). This peak obtained in this study seems very low compared to the values reported by Boujenane and Kerfal (1992) [14] and by Boujenane and Lairini (1992) [13] of 1.45 kg/d and 1.48 kg/d respectively in D'man ewes in southern Morocco. However, it is slightly higher than the peaks achieved by the Sardi breed ewes (0.88 kg/d), Timahdite (0.87 kg/d) and Beni Guil (0.91 kg/d) according to (Boujenane et al. 1996 [12]) and in the prolific ewes Avishaan (0.91 kg/d) and GMM (0.72 kg/d) according to Prakash et al (2019) [15]. In comparison with local Algerian breeds, this maximum production appears to be similar to the value obtained by Benchohra et al. (2014a) [17] of 1.07 kg/d in Rembi ewes but lower than the peak recorded by Tazegzawt ewes of 1.22 kg/d (Belkheir et al 2021 [19]).

The highest milk yield was observed during the second week of lactation in D'man ewes in this study (Figure 3). The same period of appearance of maximum production was recorded in the same breed in Morocco (Boujenane and Kerfal 1992 [14]), at Rembi ewes (Benchohra et al. 2014b [20]), at the Sardi, Timahdite and Beni Guil breeds (Boujenane et al 1996 [12]), at the prolific Avichan breed (Prakash et al. 2019 [15]) and in Pelibuey ewes (Rodríguez-Álvarez et al. 2021 [21]).

However, a peak in production was obtained in the third week of lactation in D'man ewes in Tunisia by Dhaoui et al. (2018) [22] and in the prolific Priangan breed (Tiesnamurti et al. 2012 [16]). According to Belkheir et al. (2021) [19], the maximum production value was achieved during the fourth week of lactation in Tazegzawt ewes in Algeria. The variations concerning the maximum production and the week of onset are mainly related to the effects of the genotype of the breed exploited and the experimental conditions in each study (Aboul-Naga et al. 1981 [23]).

The persistence coefficient in D'man ewes in this study was 0.94. This value seems similar to the value reported by Boujenane and Kerfal (1992) [14] and (Boujenane et al. 1996 [12]), in the D'man, Sardi, Timahdite and Beni Guil breeds, but slightly higher than the coefficient obtained by Benkobra et al (2014b) in Rembi ewes of 0.90. This high coefficient does not support the conclusion of Louda and Doney (1976) [24] that milk

production decreases rapidly when the number of suckled lambs is high.

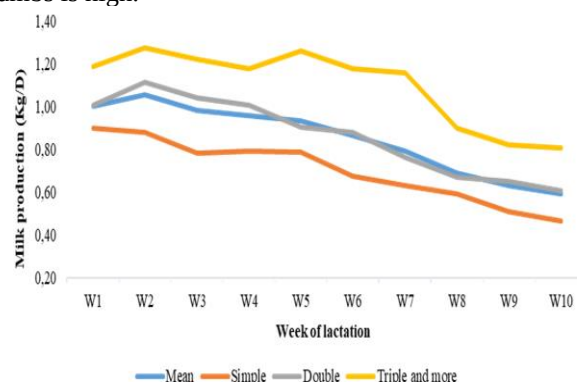


Figure 3. Lactation curve of D'man ewes as a function of number of lambs suckled

Factors of variation in milk production of D'man ewes

The analysis of variance showed that lambing rank (parity) had no significant influence on the milk production of D'man ewes (Table 4). This conclusion is consistent with the results reported by Arbouche (2010) [25] in Ouled Djellal ewes, and by Benchohra et al. (2014a) [17] who concluded that the age of the Rembi ewe has no significant effect on its milk production. However, a significant effect of parity on average daily production and total milk production was also reported by Boujenane and Kerfal (1992) [14] and (Boujenane et al. 1996 [12]) in D'man ewes in Morocco, and by Belkheir et al. (2021) [19] in Tazegzawt ewes. This factor was also significant on average daily milk production in prolific Avishaan and GMM ewes (Prakash et al. 2019 [15]).

A non-significant effect of the mother's wrestling weight on average daily, monthly and total milk production was observed in the D'man herd studied. Similarly, Prakash et al. (2019) [15] for the prolific breeds Avishaan and GMM also reported similar performance in ewes for different weight categories. However, Ángeles Hernández et al. (2018) [26] in the East Friesian breed, and Rodríguez-Álvarez et al. (2021) [21] in the Pelibuey breed reported the effect of body weight of ewes at mating, in mid-gestation, at lambing and during lactation on the milk yield of ewes. The absence of the weight effect can be justified by the mobilization of the ewe's body reserves to ensure sufficient milk production for the lambs. Therefore, good nutrition during breastfeeding is essential.

The effect of lambing season on average daily milk production and milk yield of D'man ewes during lactation was non-significant. Boujenane and Kerfal (1992) [14] deduced the same conclusion for this breed in Morocco. However, Dhaoui et al. (2018) [22] reported a significant effect of the birth season on the average daily milk yield of D'man ewes in the first, fourth, sixth and last (10) weeks of lactation. The absence of difference in the milk yield of ewes lambing at different seasons of the year confirms the high adaptability of D'man ewes to the study region's Saharan conditions, as already reported by Chellig (1992) [5].

The number of lambs suckled has a very highly significant effect ($P < 0.01$) on the milk production of mothers for the different stages of lactation (Table 4).

During the monitoring period, ewes lactating triples or more achieved a higher daily and total milk yield than those suckling double and single, as a result of greater udder stimulation. The superiority of ewes with several lambs was around 57.2% compared to ewes with single births and 28.8% compared to ewes suckling twins.

The number of lambs suckled had a very highly significant effect ($P < 0.01$) on maternal milk production for the different stages of lactation (Table 4). During the follow-up period, ewes lactating triples or more achieved a higher daily and total milk yield than those suckling double and single, as a result of greater udder stimulation. The superiority of ewes followed by several lambs was 57.2% higher than single-born ewes and 28.8% higher than ewes suckling twins. Several authors (Boujenane and Lairini 1992 [13], Boujenane and Kerfal 1992 [14], Dhaoui et al. 2018 [22]) have reported the significant effect of this factor on the milk production of D'man ewes. Similarly, Prakash et al. (2019) [15] and Belkheir et al. (2021) [19] also reported higher milk production in twin ewes.

Suckling two or more lambs increases the milk extraction capacity of the udder, which leads to an increase in milk production (Peart et al. 1972 [27]). According to Boujenane and Kerfal (1992) [14], the greater milk production of ewes suckling several lambs can be explained by the more frequent emptying of the udder, and also by the high hormonal secretions at the time of gestation which could have a positive effect on mammogenesis and lactogenesis.

Table 4. Least-squares means ($\pm$ SE) of D'man ewes' milk production

Source of Variation	N	Daily milk production	Milk production of the 1 st month (28j)	2 nd month milk production (56j)	Total milk production (70j)
Lambing rank		ns	ns	Ns	ns
1	13	0,88 $\pm$ 0,05	27,3 $\pm$ 1,61	25,0 $\pm$ 1,66	61,4 $\pm$ 3,52
2	12	0,81 $\pm$ 0,05	24,7 $\pm$ 1,93	23,2 $\pm$ 1,69	57,0 $\pm$ 3,94
3 and more	15	0,84 $\pm$ 0,04	27,1 $\pm$ 1,35	23,1 $\pm$ 1,34	58,8 $\pm$ 3,00
Weight of the ewe		ns	ns	Ns	ns
Live Weight $\leq$ 33 kg	17	0,85 $\pm$ 0,05	26,3 $\pm$ 1,35	24,3 $\pm$ 1,66	59,0 $\pm$ 3,34
33 < Live Weight $\leq$ 40 kg	15	0,84 $\pm$ 0,04	26,8 $\pm$ 1,41	23,3 $\pm$ 1,09	59,0 $\pm$ 2,64
Live Weight > 40 kg	8	0,85 $\pm$ 0,07	26,1 $\pm$ 2,74	23,7 $\pm$ 1,94	59,4 $\pm$ 5,16
Suckling lambs		**	**	**	**

1	19	0,70 $\pm$ 0,03	22,3 $\pm$ 1,19	19,4 $\pm$ 0,83	48,9 $\pm$ 2,14
2	18	0,86 $\pm$ 0,02	27,1 $\pm$ 1,03	23,6 $\pm$ 0,59	59,7 $\pm$ 1,59
3 and more	03	1,10 $\pm$ 0,03	32,9 $\pm$ 1,63	32,4 $\pm$ 1,29	76,9 $\pm$ 2,00
Lambing season		ns	ns	Ns	ns
Autumn	11	0,88 $\pm$ 0,05	27,2 $\pm$ 1,82	25,2 $\pm$ 1,64	61,6 $\pm$ 3,50
Summer	12	0,82 $\pm$ 0,05	25,3 $\pm$ 1,99	23,4 $\pm$ 1,78	57,7 $\pm$ 4,01
Spring	17	0,85 $\pm$ 0,04	26,8 $\pm$ 1,24	23,1 $\pm$ 1,31	58,5 $\pm$ 2,99
** significant to $p < 0,01$; * significant to $p < 0,05$; ns : non-significant correlation					

4. CONCLUSION

The results of this study suggest that milk production achieved by the prolific D'man ewes exploited in the oasis production system in Adrar can sufficiently meet the lactation needs of reared lambs. Quantified milk yield was significantly affected by litter size at birth. Indeed, ewes that suckled several lambs produced a higher quantity of milk than those that suckled a single lamb. This production will help to make the most of multiple lambs through low mortality and improved lamb pre-weaning growth performance. However, ewes suckling multiple lambs must be carefully assessed at lambing to eliminate mothers with low milk production.

5. REFERENCES

- [1] MADRP (Ministère de l'Agriculture et du Développement Rural et de la Pêche). Statistiques agricoles, superficies et production séries A et B, Alger. Algérie. 2015.
- [2] Djaout A, Afri-Bouzebe F, Chekal F, El-Bouyahiaoui R, Rabhi A, Boubekour A, Benidir M, Ameur Ameur A and Gaouar SBS. Biodiversity state of Algerian sheep breeds. Genetics & Biodiversity Journal 2017; 1(1): 1-18.
- [3] Foley H & Meslin R. Exploration scientifique des oasis du Gourara et de Touat (Mars-Avril 1913). Archives Institut Pasteur d'Algérie 1924; 2: 264-442.
- [4] Bouix J & Kadiri M. Un des éléments majeurs de la mise en valeur des palmeraies : la race ovine D'Man. Options Méditerranéennes (CIHEAM) 1975 ; 26 : 87-93.
- [5] Chellig R. Les races ovines algériennes. Alger : Office de publication Universitaire., 1992.
- [6] Boubekour A, Benyoucef MT, Lounassi M, Slimani A and Amiali M. Phenotypic characteristics of Algerian D'Man sheep breed in Adrar oases. Livestock Research for Rural Development 2015; 27 (7): 1-5.
- [7] Boubekour A, Benyoucef MT, Benidir M, Slimani A, Maaref A et Lounassi M. Qualités reproductives des brebis D'Man en oasis algériennes. Livestock Research for Rural Development 2019; 31(8).
- [8] Derqaoui L, Avènement de la puberté chez les races ovines D'man et Sardi et leurs produits de croisement. In : Rencontres autour des Recherches sur les Ruminants, INRA et Institut de l'Élevage (éd.) : 10e Journées 3R, 2003.
- [9] Boubekour A et Benyoucef MT. Fonctionnement d'élevage des petits ruminants dans l'oasis de Tilloulène, Sud-ouest algérien. Options méditerranéennes (CIHEAM) 2014; série A, 108: 397-401.

- [10] Ricordeau G, Boccard R & Denameur R. Mesure de la production laitière des brebis pendant la période d'allaitement. *Annales de Zootechnie* 1960 ; 9 (2) : 97-120.
- [11] Ünal N, Atasoy F, Akçapınar H, Koçak S, Yakan A, Erol H and Uğurlu M. Milk yield measured by oxytocin plus hand milking and weigh-suckle-weigh methods in ewes originating from local crossbred in Turkey. *Revue de Médecine Vétérinaire* 2007; 158 (6): 320-325.
- [12] Boujenane I, Berrada D, Mihi S & Jamaï M. Production laitière des brebis de races Timahdite, Sardi et Béni Guil en race pure et en croisement. *Revue Marocaine des Sciences Agronomiques et Vétérinaires* 1996 ; 16 (3) : 11-18.
- [13] Boujnane I and Lairini K. Genetic and environmental effects on milk production and fat percentage in D'Man and Sardi ewes and their crosses. *Small ruminant research* 1992;8 (3) : 207-215.
- [14] Boujenane I & Kerfal M. Estimation de la production laitière des brebis D'Man. *Al Awamia* 1992; 78: 145-155.
- [15] Prakash V, Sharma RC, Prince LLL and Kumar A. Milk yield potential of prolific Avishaan and GMM sheep and their association with overall ewe productivity. *Indian Journal of Small Ruminants* 2019; 25 (1): 25-30
- [16] Tiesnamurti B, Inounu I, Subandriyo and Martojo H. Milk production capacity of priangan prolific sheep: II. The lactation curve. *Jurnal Ilmu Ternak dan Veteriner* 2012; 8 (1): 17-25.
- [17] Benchohra M, Boulkaboul A, Aggad H, Amara K, Kalbaza A Y et Hémida H. Production laitière, croissance et comportement des agneaux chez le mouton Rembi en période d'allaitement. *Algerian journal of Arid Environment* 2014a ; 4 (2) : 31-41.
- [18] Benyoucef MT et Ayachi A. Mesure de la production laitière de brebis Hamra durant les phases d'allaitement et de traite. *Annales de zootechnie (INRA)* 1991; 40 (1): 1-7.
- [19] Belkheir B, Ikken L, Benhamed N, Ghoulane F, Benidir M, Bousbia A & El Bouyahiaoui R. Potentialités laitières de brebis Tazegzawt Bleues de Kabylie et croissance des agneaux. *Livestock Research for Rural Development* 2021; 33(7):1-7.
- [20] Benchohra M, Kalbaza A Y, Amara K et Aggad H. Estimation de la production laitière chez les brebis Rembi par la méthode de la double pesée et celle de l'ocytocine suivie de traite manuelle. *Revue Ecologie-Environnement (Algérie)* 2014b ; 10 : 61-65.
- [21] Rodríguez-Álvarez HA, Hinojosa-Cuellar JA, González-Garduño R, Gallegos-Sánchez J, Rubio-Rubio M, Aranda-Ibáñez E M, Oliva-Hernández J and Torres-Hernández G. Lactation Curve, Milk Production of Pelibuey Ewes and Preweaning Growth Rate of the Lambs. *Agro Productividad* 2021; 14.
- [22] Dhaoui A, Chniter M, Atigui M, Dbara M, Seddik M M and Hammadi M. Factors affecting the milk yield and composition over lactation of prolific D'man ewes in Tunisian oases. *Tropical Animal Health and Production* 2018; 51: 507-518.
- [23] Aboul-Naga AM, El-Shobokshy AS and Moustafa MA. Milk production from subtropical non-dairy sheep. 2. Method of measuring. *The Journal of Agricultural Science* 1981; 97(2): 303-308.
- [24] Louda F and Doney JM. Persistency of lactation in the improved Valachian breed of sheep. *The Journal of Agricultural Science* 1976 ; 87 (2) : 455-457.
- [25] Arbouche Y. Effet de la synchronisation des chaleurs de la brebis Ouled Djellal sur les performances de la reproduction et de la productivité en région semi-aride. *Mémoire de magister, Université Ferhat Abbas, Sétif, Algeria*. 2010.
- [26] Ángeles Hernández JC, Schilling SR, Vera Arias MA, Echeverría Pérez RA, Castelán-Ortega OA, Ramírez Pérez AH and Ronquillo M G. Effect of live weight pre- and post-lambing on milk production of East Friesian sheep. *Italian Journal of Animal Science* 2018; 17(1): 184-194.
- [27] Peart JN, Edward RA and Donaldson E. The yield and composition of the milk of Finish Landrace x Blackface ewes: Ewes and lambs maintained indoors. *The Journal of Agricultural Science* 1972: 79 (2): 303-313.

NUTRITIONAL AND SENSORY CHARACTERIZATION OF SOME FERMENTED FOOD PRODUCTS MADE IN THE CARPATHIAN-DANUBIAN-PONTIC AREA

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Abstract

The territory of Romania has been known as the Carpathian-Danubian-Pontic space since ancient times, being traversed from one end to the other by the Carpathian Mountains and being bordered to the south by the Danube River (Danubius) which flows into the Black Sea (Pontic area). Fermented food products manufactured in Romania belong to the many categories, such as: lactic acid dairy products or fermented dairy products (yogurt, sana, buttermilk, kefir, fermented cream, fresh cheese), pickled vegetables (cabbage, cucumbers, red pepper), non-alcoholic fermented beverages (braga, borsch, vinegar, socata), traditional fermented bread, matured cheeses, raw dried salami and alcoholic beverages (beer, wine). In the present article we will focus on a nutritional and sensory characterization of the most famous fermented products that are manufactured almost exclusively in the Carpathian-Danubian-Pontic area, of course also due to the influence of the neighbours, this being: fermented dairy products (yoghurt, sana and buttermilk), lactic fermented pickles (pickled cabbage) and non-alcoholic fermented drinks (braga, borsh and socata).

Keywords: fermented food, nutritional characterization, sensory evaluation, yoghurt, pickled cabbage, non-alcoholic fermented beverages

1. INTRODUCTION. FERMENTATION PROCESS APPLIED TO FOOD.

Fermentation is an ancient food preservation technique, being considered one of the oldest known uses of biotechnology. Fermentation was initially developed to allow a longer storage of raw materials (milk, meat, cereals, vegetables, etc.), so as a preservation method, later the beneficial effects on health were also noted. The functional nature of this process determines the obtaining of foods with excellent sensory and nutritional attributes and with a beneficial probiotic effect on health. Fermentation is a natural process by which microorganisms (yeasts, bacteria and sometimes moulds) transform the carbohydrates contained in food products - such as starch, sugar, lactose - into alcohol or acids, acting as natural preservatives, also giving a distinct flavour for the fermented products.

Food fermentation process can be classified in two main directions, namely:

- ✓ acid fermentation
- ✓ alcoholic fermentation.

Through acid fermentation, which is carried out by bacteria, a large amount of acid (lactic, acetic, propionic) is produced, but also a variety of other metabolites (flavours, vitamins), which lead to more complex organoleptic properties of fermented foods.

Alcoholic fermentation is carried out by yeasts and leads to the release of ethanol (alcohol) and carbon dioxide. *Saccharomyces* is by far the most commonly used yeast in food fermentation, and a large number of strains coming from these bacteria have been selected for the fermentation of: bread, beer, wine and other products.

The mechanism behind the preservation of food, through the fermentation process, was clarified in 1857, by Louis Pasteur who identified the so-called "lactic acid bacteria" as a promoter of obtaining lactic acid.

The time required for the fermentation process varies from a few days to a few months.

Like humans, in order to grow and develop, microorganisms need a source of food and an environment conducive to development.

Thus, for the fermentation process to take place, a source of food is necessary for the development of microorganisms, the source which usually consists of the simple sugars present in a food product. Another source of food for the microorganisms that lead the fermentation is the nitrogen present in the proteins of the raw material and which contributes, as in the case of humans, to the growth and development of the mass of microorganisms.

In addition to these 2 nutritional factors, for the success of a fermentation process, it is necessary to ensure certain parameters for the development of fermentation microorganisms, namely: temperature, acidity, pressure, humidity. Afterwards, the fermented foods are usually stored in a cool place to slow down any further fermentation, so to prevent spoilage of the end products. Thus, by excessively increasing the number of good bacteria in a food, harmful microorganisms (pathogens) are unable to reproduce and grow, thus preventing food spoilage. The acidic, low-oxygen environment and the addition of salt help to develop a habitat that is friendly to good bacteria and hostile to potentially harmful microorganisms (for bacteria - yeasts and molds and for yeasts - bacteria).

Fermented foods have different shelf lives, depending on the type of raw material, storage temperature, packaging method or any other subsequent processing of the fermentation process.

Thus, acid dairy products can be kept for several days to weeks, fermented vegetables for 6 months - 1 year, fermented cheeses and salamis for several months and wine and vinegar can be kept for years.

Some fermented foods that are pasteurized after fermentation no longer contain live microorganisms and thus no longer offer the same health benefits, but have a longer shelf life.

Fermentation can be natural when it occurs spontaneously and thus products of plant origin can be fermented: fermented vegetables, fermented cereals, pickled cabbage. In addition, many wines and even some fermented sausages and beers are also obtained through natural fermentation. Other fermented foods are obtained by adding selected cultures (yeasts or bacteria, or even molds). In general, fermented dairy products, cheese and raw-dried salami are usually obtained using selected cultures because in this way a controlled fermentation is ensured and a high safety in consumption.

2. HEALTH BENEFITS, FOOD SAFETY AND SIDE EFFECTS IN THE CONSUMPTION OF FERMENTED PRODUCTS

Fermentation develops a series of beneficial bacteria, some of them known as probiotics. Many people know probiotics as "good" or "gut-friendly" bacteria, and *Lactobacillus* or *Bifidobacterium* strains are the most well-known. Probiotics are live microorganisms that provide health benefits to the human body and there are countless studies which have found that fermented foods are often more nutritious than their unfermented form, while also having a probiotic effect.

The FAO / WHO organization defined probiotics in 2002 as "live microorganisms which confer a health benefit to the host, when are administered in adequate amounts". Maintaining the viability of these microorganisms until the end of the validity period imposes certain technological requirements on the manufacture of probiotic food product. Thus, in order to bring health benefits to the consumer, the minimum number of microorganisms must be guaranteed until the end of the validity period, in the amount of at least 10^7 - 10^8 colony forming units (CFU) / ml or g.

The human gastrointestinal tract hosts more than 10^{12} microorganisms that form a complex ecosystem known as **microbiota** or **microbiome**. This ecosystem provides protection against pathogens, helps extract nutrients from ingested food, and modulates the immune system. Fermented foods are considered safe for most people to consume, but some people may experience adverse reactions. Due to the high probiotic content of fermented foods, the most common side effect is an initial and temporary increase of gas formation and bloating. These symptoms may be worse after eating high-fiber fermented foods like pickled cabbage, but it's important to remember that not all fermented foods are created equal.

Some products can contain high levels of added sugar, salt and fat - so it is important for consumers to read the nutrition label to ensure they are making a healthy choice. Thereby, if there are problems with the heart and it is the case of maintaining a diet, the consumption of pickles vegetables is not recommended, even if they have a low caloric density, because they contain a lot of salt.

The practice of fermentation is actually simple, accessible and applied in many households in the Carpathian-Danubian-Pontic area, because it requires only a few ingredients and can lead to saving money, while adding variety, new flavors and interesting textures to the diet. Vegetables such as: cabbage, beetroot, cucumbers, red peppers and carrots are some of the easiest foods to ferment at home, because the living bacteria from their surface determinate the fermentation process to take place naturally.

In order to maintain food safety when fermentation is applied in the home kitchen, the recipes must be followed closely because incorrect temperatures, fermentation times or non-sterile equipment can cause the spoilage of the obtained products, which makes them no longer safe for consumption.

3. ACID LACTIC DAIRY PRODUCTS

The fermentation processes that can be applied to milk are the following:

- lactic fermentation, carried out by lactic bacteria, which leads to obtaining acidic dairy products (yoghurt, sana, sour milk, fermented cream, fresh cheese),
- alcoholic fermentation, carried out in symbiosis with lactic fermentation, which leads to obtaining kefir,
- the propionic fermentation given by the propionic bacteria, which leads to obtaining cheeses with holes in the paste,
- the fermentation caused by the development of yeasts or moulds, in general, on the surface of the cheeses, with the formation of aromatic compounds.

In general, fermented dairy products are the only products whose label states that they contain live lactic cultures or live ferments. According to the CODEX Alimentarius standards, in order to make such a mention on the label, the minimum number of lactic bacteria that initiated the fermentation must be in the yogurt in the amount of at least 10^7 UFC per g (CODEX STAN 243-2003).

If other live microorganisms, such as probiotics, are indicated on the label, they must be present in a proportion of 10^2 UFC per g, at the end of the validity period.

Acid dairy products also known as fermented dairy products, are products made from milk or from milk derivatives (whey, buttermilk, cream) that are subjected to the lactic fermentation process.

Lactic fermentation is carried out by cultures of lactic bacteria that transform lactose from milk into lactic acid and other metabolites (flavours, vitamins). To carry out lactic fermentation, it is necessary to maintain optimal temperatures for the development of lactic bacteria.

Thereby, the fermentation of yogurt takes place optimally, at temperatures of 40-45°C (thermophilic fermentation), while the fermentation of sour milk and sana or cream takes place at lower temperatures between 20-28°C (mesophilic fermentation).

The lower the fermentation temperature, the longer the fermentation time is and thus more flavour substances can be formed. Yogurt can be obtained in a 3-6 hour interval, sour milk, sana and fermented cream require an interval of 16 hours, so that the fermentation process can take place optimally.

Fermentation is considered finished when the coagulum has formed (a compact mass of proteins, fat and liquid mass in the form of whey), and the pH of the product drops below the value of 4.6, considered the pH of coagulation of milk proteins.

Below will be presented the particularities of obtaining some fermented dairy products obtained in the Carpathian-Danubian-Pontic region:

Yogurt is the most studied and best-known fermented milk product in which, in addition to the lactic bacteria in the fermentation process, probiotics can also develop with a positive effect on health.

Due to the proximity to the Bulgarian neighbours in the Carpathian-Danubian-Pontic space, yogurt has been manufactured since ancient times, first at home with the help of spontaneous microflora and then industrially under controlled conditions with the help of selected bacteria. Yogurt consumption in Romania consists of 65% set yogurt or spoonable yogurt and 35% drinking yogurt.

According to the technical definition, yogurt is an acidic dairy product manufactured by fermentation of milk by cultures of *Streptococcus thermophilus* and *Lactobacillus bulgaricus*. By fermenting lactose, these bacteria create an acidic environment, favourable for the absorption of calcium in a rather large proportion and also cause a significant increase in the digestibility of the raw material.

Sana and **sour milk** are fermented dairy products that are obtained exclusively in Romania and are an invention of the milk industry from the '50s that wanted to copy the fermented milk produced in Romanian homes at that time, also known as "covasit" milk. Thus, the fermentative process takes place over a longer period of time (mesophilic fermentation), the difference between them being the fact that sana is a acid dairy product, with a higher fat content than sour milk and the number of flavour formation bacteria from the fermentation culture are double than in sour milk.

3.1. Nutritional characterization of fermented dairy products

Probiotics and lactic bacteria that develop in fermented dairy products give the body a series of benefits, among which we mention:

- synthesis of vitamins, such as: vitamin B₁, B₂, B₆, B₁₂, K and folic acid and source of minerals, such as: calcium, potassium, phosphorus. These minerals are essential for several biological processes, such as blood pressure regulation, metabolism and bone health.
- stimulating the well-being of the intestines, alleviating the symptoms of irritable bowel

syndrome and removing the unwanted manifestations of diarrhea and constipation, thanks in particular to the probiotic content

- achieving a better digestibility of proteins and carbohydrates (lactose) contained in raw milk. Because lactose is broken down during the fermentation process, people with lactose intolerance can more easily tolerate fermented dairy products such as: yogurt and fresh cheese.
- protection against osteoporosis. Acid dairy products contain several key nutrients for maintaining bone health, including calcium, protein, potassium, phosphorus, in an appropriate proportion.
- help in regulating body mass. The consumption of yogurt and fermented milk is associated with weight loss and better weight control because these products have a high protein content, from which, through fermentation, peptides with the role of reducing appetite (peptide YY and GLP-1).
- maintaining the health of the cardiovascular system through the richness of group B vitamins, especially vitamin B₁₂ and riboflavin. Dairy fermented products have been found to modestly lower blood pressure and cholesterol levels. The fat content of acid dairy products is one of the reasons why the beneficial effect on the heart is often controversial, since it consists mainly of saturated fat, with a small amount of unsaturated fatty acids. But some research has shown that the intake of saturated fats from fermented dairy products increases the blood parameter HDL cholesterol (considered "good" cholesterol), which can protect heart health.
- improving brain function. Fermented dairy products have been shown to improve cognitive function in adults due to their high content of B vitamins.

All the health benefits related to the consumption of acid dairy products and their influence on the immune, cardiovascular and nervous systems have begun to be studied recently and therefore more research is needed in the field to reach a unanimously accepted conclusion. In general, dairy products that consistently contain higher levels of microorganisms (10⁹ CFU/ml or g) are a good source of live lactic acid bacteria that can provide the above mentioned benefits to human health.

From a nutritional point of view, the nutritional declaration of several acidic dairy products present on the Romanian market is presented below.

Table 1. The average nutritional declaration for 100 g of acid lactic products

Nutritional declaration for 100 g of product	Set yoghurt with 3,7% fat	Drink yoghurt with 0 % fat	Spoonable yoghurt with 2,8 % fat	Sourmilk with 2 % fat	Sana with 3,6% fat
Energy, kJ/ kcal	264/63	155/37	228/54	190/45	244 /59
Fat from which, g	3.7	0.1	2.8	2	3.7
Saturated fats, g	2.2	0.06	1.7	1.2	2.2
Carbohydrates, from which, g	4.2	4.5	3.6	3.9	3
Sugars, g	4.2	4.4	3.6	3.9	3
Proteins, g	3.3	4.4	3.7	2.9	3.3
Salt*, g	0.1	0.1	0.1	0.1	0.1

As can be observed, the caloric density of 100 g of Romanian acid dairy products is quite low (63 kcal/100 g maximum), therefore they can be used successfully in weight loss diets. The salt content expressed in the table is due exclusively to the presence of sodium in the milk like raw material.

3.2. Sensory characterization of fermented dairy products

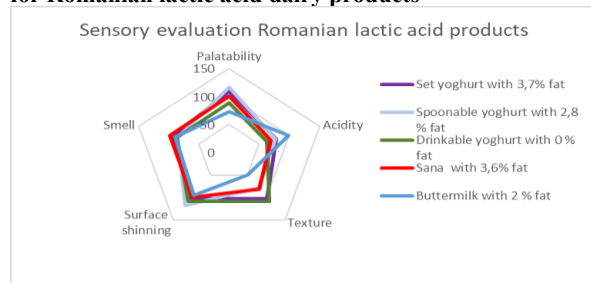
Due to the fact that acid dairy products were the subject of my doctoral thesis, they were studied closely and from a sensory point of view with the help of a number of 30 untrained tasters who provided feedback on the defining sensory characteristics of these products. For this reason, the determination scale exceeds the value of 100 because it was obtained by the arithmetic mean of the points given by each taster.

Therefore, the results of this sensory test, which were based on hedonic analysis, can be found in Table 2, and their graphic representation in the form of a spider graph can be found in Figure 1.

Table 2. Sensory characteristics of lactic acid dairy products

Type of lactic acid products	Palatability	Acidity	Texture	Surface shining	Smell
Set yoghurt with 3,7% fat	109	78	103	102	93
Spoonable yoghurt with 2,8 % fat	117	77	79	117	85
Drinkable yoghurt with 0 % fat	88	63	109	108	87
Sana with 3,6% fat	101	69	81	99	98
Buttermilk with 2 % fat	73	99	50	95	89

Figure 1. Grafic representation of sensory characteristics for Romanian lactic acid dairy products



From this graph can be observed that the best appreciate Romanian lactic acid products is yoghurt with higher content of fat which confer smoothness, creamy texture and appealing shinnines of the surface.

4. LACTIC PICKLED VEGETABLES

Pickled cabbage is a lactic fermented vegetable preserved in a salty solution in which fresh, cleaned cabbage is introduced. The traditional fermentation process, which does not differ much from the industrial one, applied to cabbage involves the following steps: the cabbage is cleaned, its spine is removed (if it is desired to be preserved whole) or it is finely cut or shredded and then it is placed in layers in a large vessel, usually a wood barrel or glass jar. The next step is adding salt between the layers of cabbage or sprinkle salt on each head of cabbage to favour the extraction of water from

each cabbage and to start the fermentation process. The fermentation process can last several weeks or months, depending on personal preferences and storage conditions, and from time-to-time air is bubbled in the fermentation vessel for better development of lactic bacteria, which are aerobic bacteria.

Pickled cabbage can be kept for a long period of time under proper storage conditions, usually in a cool, dark place. Fermentation can continue and thus add complexity and more flavour to the pickled cabbage as time passes.

4.1. Nutritional characteristics of pickled cabbage

Pickled cabbage is an excellent source of probiotics, beneficial for intestinal health, contributing to maintaining a healthy balance of intestinal flora and improving digestion and absorption of nutrients. Regular consumption of pickled cabbage can help stimulate the secretion of digestive enzymes and improve intestinal transit, thanks to the lactic acid and fibre content, which also plays a prebiotic role. This is also due to the content of acetylcholine in pickled cabbage, a neurotransmitter identified in the central nervous system that transmits messages from the brain to the body through nerve cells. The bacteria present in pickled cabbage can also help in of increase the body's resistance to infections and improve the immune response to pathogens.

Likewise, the consumption of pickled cabbage can also help to reduce inflammation in the body, through the content of antioxidants and anti-inflammatory compounds formed as metabolites of lactic fermentation. Last but not least, pickled cabbage is a rich source of vitamins and minerals, including vitamin C, vitamin K, folic acid, iron and calcium, nutrients contained both in the raw material and formed as metabolites of fermentation.

From a nutritional point of view, 2 varieties of pickled cabbage present on the Romanian market were chosen, whose nutritional declaration is presented in table 3.

Table 3. Nutritional declaration for 100 g of pickled cabbage (without brine)

Nutritional declaration for 100 g of product	Pickled cabbage 1	Pickled cabbage 2
Energy, kJ/ kcal	112/27	59/14
Fat from which, g	0.1	0.1
Saturated fats, g	0	0.1
Carbohydrates, from which, g	4.3	2
Sugars, g	1.8	1
Proteins, g	2.5	1.2
Salt, g	0.9	0.7

As can be seen, the caloric density of pickled cabbage is quite low (maximum 27 kcal/100 g), being obtained from a low fat and protein content, but given the content of carbohydrates and especially other fibres present in cabbage raw material. The salt content of the brine can reach the value of 3%, but in the nutrition table it is only the salt content of the drained pickled cabbage, so what the cabbage has absorbed from the brine.

4.2. Sensory characterization of pickled cabbage

Pickled cabbage made in Romania has a sour and salty taste, with an intense and rich aroma, given especially by fermentation added spices. The fermentation process adds a level of sensory complexity, and the cabbage can also have subtle aromas of spices or other ingredients that are added in the fermentation process, namely: bay leaves, black pepper or garlic.

Pickled cabbage is highly appreciated by Romanian consumers and can be consumed as such, in the form of a salad to which olive oil and ground pepper or ground paprika are added, depending on the area of the country where it is consumed. It is also consumed as a food usually prepared in the oven, highly appreciated, namely in the form of sauteed cabbage. The leaves of pickled cabbage are used to cover the “sarmale”, usually made from pork, a very popular dish in Romania, so that their acidity counteracts the fat in the “sarmale”.

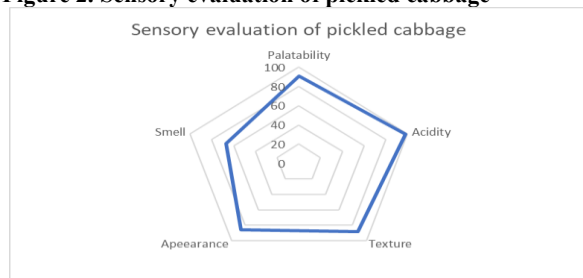
From the point of view of the appearance, the pickled cabbage is immersed in a liquid with high turbidity, quite opaque and showing some effervescence.

The smell of pickled cabbage varies in intensity and the nature of the smell, from sour to sweet or pungent, being often accompanied by the aromas of spices or added spices. There are people who do not appreciate the smell of pickled cabbage, especially when it was not aerated during fermentation or the proper hygiene conditions were not respected, and therefore, in addition to the usual metabolites obtained through lactic fermentation, there are also compounds with nitrogen or sulphur that creates an undesirable smell.

From a taste point of view, we can say that the main taste of pickled cabbage is the sour one accompanied by the salty taste, but also with secondary flavours, given by the vegetables or spices added in the fermentation process. The texture of pickled cabbage is elastic and soft, but not excessively soft.

Figure 2 graphically presents a series of sensory characteristics of Romanian pickled cabbage from the point of view of an authorized food taster.

Figure 2. Sensory evaluation of pickled cabbage



5. FERMENTED NON-ALCOHOLIC BEVERAGES (BRAGA, BORSH, SOCATA)

Braga is a refreshing drink that was made by the ancient Greeks who lived on the territory of Romania and is specific to the Danubian-Pontic area, i.e. in the counties: Braila, Galati, Giurgiu, Mehedinti and Constanta. Braga

is a cloudy, mucilaginous refreshing drink with colloidal substances in suspension and with a high content of nutritious components obtained after fermentation. The fermentation process of this drink begins with a short alcoholic fermentation, initiated by yeasts, which is then replaced by a lactic fermentation with the formation of lactic acid, given by the lactic bacteria present in the flour.

The raw material for the manufacture of this drink consists of various types of flour: rye, corn, wheat, some of which are baked in the oven at temperatures of 100-105°C. These flours are hydrated with water, to which brewer's yeast is added and left to ferment for 4-5 days. Sugar is added on top of this liquid to create the degree of sweetness specific to this drink. The lactic acid obtained through fermentation gives the drink a pleasant, aromatic and fresh taste.

Borsh is a sour, tasty drink, obtained by the lactic fermentation of wheat bran mixed with corn flour immersed in boiled and cooled water. Other ingredients are also used for flavouring, such as: cherry sprig, dill and lovage.

Borsh is used especially in the region of Moldova for souring soups, but it can also be consumed as a refreshing drink due to the beneficial effects it has on the body. Industrially, the borsh is pasteurized and then bottled, which causes an extension of its shelf life.

Socata is a traditional soft drink popular in our country but also in neighbouring countries such as: Bulgaria and Serbia. Socata is a refreshing drink obtained by the fermentation of elder flowers (*Sambucus nigra*) and sugar, and a percentage of lime juice, which gives it a refreshing and slightly sweet taste. The fermentation process is generally applied at home and has as its raw material the elderflowers picked during the period of maximum flowering, namely at the end of spring or the beginning of summer. The elderflowers are washed and placed in a large glass jar over which warm water is poured, sugar and lemon juice are added, as well as lemon slices. The mixture is left to ferment for several days or weeks, depending on how effervescent we want to get the refreshing drink. The fermentation is alcoholic and allows the development and extraction of the aroma of the elderflowers, as well as the creation of an effervescence due to the carbon dioxide formed.

After the end of fermentation, the refreshing drink is filtered by the solid remains of elderflowers and lemons and bottled in glass containers, then stored in cold conditions. If you want to extend the shelf life of this drink, you can easily pasteurize the bottles with the product, followed by a slow cooling.

5.1. Nutritional characteristics of fermented non-alcoholic beverages

The benefits of braga are multiple, because it is obtained from natural ingredients and can be considered a healthy alternative to carbonated juices. Braga contains a complex of vitamins from group B (B₁, B₂, B₃, B₆, B₁₂) formed after the fermentation process, proteins and

minerals (phosphorus, calcium, iron and zinc). The presence of varied microflora in braga, formed especially by lactic bacteria and yeasts, considered probiotics, has a beneficial influence on the digestive system and bactericidal properties, and the carbon dioxide formed in small quantities helps digestion. However, due to the rather high content of sugars, this refreshing drink should be consumed with caution.

Borsh has an important effect of strengthening the immune system, antibacterial and antiviral properties. Also, borsch can be considered a digestive adjuvant, ensuring good functioning of the colon, due to the fact that through lactic fermentation, a series of probiotic bacteria are found in it, such as: *Lactobacillus acidophilus* and *Bifidobacterium bifidus*. Due to the very low caloric content (4 kcal/100 ml), it is recommended for people who want to lose weight, stimulating fat burning.

The bran used as the first step in obtaining borsch is a good source of fibres, and the borsch prepared from them can preserve some of these fibres, with a beneficial effect on maintaining intestinal health and regulating intestinal transit. Being a lactic fermentation as metabolites, small amounts of vitamins and minerals can be obtained from the fermented bran, such as vitamin B and some essential minerals, although in quite small amounts compared to other food sources. Borsh can also represent a natural remedy for hangovers, due to its acidity, and can be recommended to patients with anaemic conditions, as it can restore appetite, eliminate apathy and the feeling of drowsiness associated with this condition. Socata is often served cold, with ice, and can be diluted with water or added to cocktails or other drinks.

Socata is generally considered a low-calorie soft drink (when not overly sweetened), but which also does not provide a significant amount of essential nutrients. Although elderflowers contain certain nutrients, such as vitamin C and antioxidants, but the amount of these in the socata is usually very low, so the socata does not represent a significant source of vitamins and minerals. In table 4, the nutritional declarations of the 3 non-alcoholic fermented drinks available on the Romanian market are presented.

Table 4. Nutritional declaration for fermented non-alcoholic beverages

Nutritional declaration for 100 ml of product	Socata	Braga	Borsh
Energy, kJ/ kcal	174/41	410/97	19/4
Fat from which, g	0.3	0.15	0
Saturated fats, g	0	0	0
Carbohydrates, from which, g	9.5	22.2	0.6
Sugars, g	8.7	12	0
Proteins, g	0	1.2	0.2
Salt, g	0.1	0.1	0.4

As can be seen from this table, borsch from bran has the lowest caloric density (4 kcal/100 ml), and braga, due to the content of sugar and total carbohydrates, has the highest caloric density (97 kcal/100 ml).

The fat content of these soft drinks is insignificant, as is the protein content, which is slightly higher in braga due to the fact that in suspension there are also particles from the pregelatinized flours used as raw materials.

5.2. Sensory characteristics of fermented non-alcoholic beverages

Borsh. The color of this fermented drink is light and starts from pale yellow to amber. It can sometimes have a slight brown tint depending on the fermentation time and other ingredients added. Due to the bran in suspension, it may have sediment that, by stirring, disturbs the appearance of the borsh.

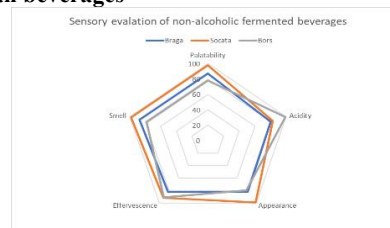
The smell of bran borsch is acidic, with slightly sweet notes due to the spices used in fermentation. The taste of borsch is sour, with a slight hint of bran, comparable to that of other fermented beverages, such as kombucha. The texture of bran borsch is liquid, but thanks to the bran remaining in suspension, a slightly dusty consistency can be obtained.

Socata. The color of the socata can vary from a slightly yellowish turbidescence color to a darker yellow, with fine bubbles due to the presence of carbon dioxide resulting from fermentation. The aroma of socata is distinct, easily recognizable, fresh and floral, with subtle notes of elderflower and lemon. Socata has a refreshing and slightly sweet taste, with a subtle balance between the natural sweetness of elderflowers and the acidity of lemon or other added fruits. The texture of socata is usually fluid and slightly effervescent, due to the fermentation process. In general, socata is valued more for its pleasant taste and refreshing properties than for its nutritional value. It's a healthy alternative to sugary fizzy drinks and can be a refreshing and enjoyable option during hot summer days. However, it should be consumed in moderation, especially in the case of excessively sweetened versions, due to the sugar content. Braga is usually golden-brown to dark brown in color with high turbidity due to sediments or particles resulting from the fermentation process.

The smell of braga is complex, with sweet and intense notes of roasted cereals and sometimes chocolate, and the taste is characterized by a balance between sweetness and acidity, with a distinct note of effervescence due to fermentation. The texture of braga can vary from liquid to slightly viscous or full, with a slight effervescence due to fermentation.

In Figure 3, the sensorial evaluation of the 3 fermented alcoholic beverages present on the Romanian market is graphically represented.

Figure 3. Sensory evaluation of non-alcoholic fermented Romanian beverages



As it can be observed, the most appreciated fermented soft drink of these 3 is socata, braga not being so appreciated due to its cloudy consistency, and borsh due to its acidity and specific smell.

6. CONCLUSIONS

Fermentation is a food processing technology that favors the development and metabolic activity of microorganisms for the transformation of raw materials (milk, vegetables, cereals, meat, fruits, flowers) into fermented food products, mostly with a probiotic effect, such as: fermented dairy products, fermented cheeses, pickles vegetable, raw dried salami, bread, beer, wine, vinegar, cider, socata. The consumption popularity of fermented foods and drinks is due to their improved shelf life, food safety in general, their functionality and sensory properties, but also their nutritional properties. The latter include the presence of bioactive molecules, vitamins and other constituents with increased bioavailability, which were formed following the fermentation process. Many fermented foods also contain live microorganisms that can improve gastrointestinal health. Recently, there is an increased interest in the consumption of fermented food products, interest determined mainly by the benefits they bring to health, and the trend will continue in the future, due to the prevalence of metabolic syndromes, such as: obesity, various food allergies and intolerances (lactose, gluten), lifestyle choices (vegetarianism and veganism), as well as the growing interest of consumers in all that is perceived as natural and promotes health and even longevity.

7. REFERENCES

- [1] A.C. Ouwehand, H. Röytiö, in *Advances in Fermented Foods and Beverages*, 2015
- [2] C. Banu, s.a. – *Biotehnologii in industria alimentara* - Editura Tehnica, Bucuresti, 2000
- [3] C. Banu, s.a. – *Biotehnologii in industria alimentara – folosirea enzimelor si microorganismelor in industria alimentara*– Editura Tehnica, Bucuresti, 1987
- [4] Dan Valentina – *Microbiologia alimentelor* – Editura Alma, Galati, 2001
- [5] G.M. Costin, s.a. – *Produse lactate fermentate* – Editura Academica, Galati, 2005
- [6] <http://www.fao.org/3/x0560e05.htm>
- [7] <https://coolinarie.com/2011/06/30/bors-de-tarate/>
- [8] https://origini.ro/despre-hrana/31_-Ritmul-natural-al-realiz%C4%83rii-o%C5%A3etului-de-mer.html
- [9] <https://science.howstuffworks.com/innovation/edible-innovations/beer4.htm>
- [10] <https://www.brainhq.com/brain-resources/brain-healthy-foods-nutrition/brain-alcohol>
- [11] <https://www.frontiersin.org/articles/10.3389/fmicb.2018.01785/full>
- [12] <https://www.healthline.com/nutrition/8-fermented-food>
- [13] <https://www.healthline.com/nutrition/fermentation>
- [14] <https://www.heartfoundation.org.nz/about-us/news/blogs/fermented-foods-the-latest-trend>
- [15] <https://eatntrack.ro/calorii>
- [16] <https://www.doc.ro/dieta-si-sport/varza-murata-si-zeama-de-varza-ce-beneficii-au-pentru-sanatate>

WHAT MESSAGE DOES WINE SEND TO THE CONSUMER THROUGH THE LABEL

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Abstract

Wine is a complex product that goes from the concept of food to that of hedonic drink in the perception of consumers. In this context, it is very important for wine producers to understand the factors of perception of consumer quality but also the relative importance they attach to these factors when deducting the quality of wine to meet these expectations, needs or desires. The existing label on a bottle of wine must contain practical and accurate information so that the consumer makes the purchase decision instead of a similar products. Buying wine in the retail store system (specialized stores) should not hurt more than ten minutes (2003, Schnettler and Rivera). So, both the information on the label and the product evaluation will be closely related to the time consumers need to observe and analyze them (2017, Krishna et al.). If we include the information such as: the designation of origin, therapeutic recommendations, nutritional information, have a great influence on the intention to purchase and as a result this aspect requires in-depth studies. Content is especially important for experienced consumers who are looking for relevant information available to be sure of their purchase. This article presents importance to wine specialists, experts, research, as a starting point in understanding information about consumers behavior for the same products and markets. They can be used as a guide to identify similarities in consumer behaviors for different products with wine-like features. We aim to complement this research with recent findings and conclusions related to consumer behavior by studying culture and noting differences in the country, culture, religions or races in wine consumption. We can provide a general picture of the current state of education of the factors of perception of wine quality through sensory analysis. To this end, the factors determining the perceived state of the wine as a product, the state of the consumer and the state of consumption shall be analyzed first. Then, the most widely used methodologies are discussed to study the hedonic sense of consumers. Finally, the characteristics of wine related to the perception of the quality are evaluated.

Keywords: wine, label, design, consumer.

1. INTRODUCTION

Wine is a complex product that goes from the concept of food to that of hedonic drink in the perception of consumers. In this conclude, it is very important for wines producers to understand the perception of the factors of for consumer quality but also the relative importance they add to these factors since deducting the quality of wine to meet these expectations, needs or desires.

We can provide a general picture of the current state of education of the factors of perception of wine quality through sensory analysis. To this end, the factors determining the perceived state of the wine as a product, the state of the consumer and the state of consumption shall be analyzed first. Then, the most widely used methodologies are discussed to study the hedonic sense of consumers. Finally, the characteristics of wine related to the perception of the quality are evaluated.

If we refer strictly to the naming the origin and information about nutritional level, they must be very visible in the wine label, which may be a stimulus in the purchase decision (Gutman, 1982).

We can say that these are useful knowledge to impose on the consumer the experience that can be produced when savouring the product. Experienced consumers make a more careful and complete analysis of the label than consumers with less experience and significantly analyse the greater amount of information written on the label, which is, given that they can distinguish and compare different types of wine, by category, by analysing the exposed information (Solomon, 1997). But a large amount of knowledge requires additional cognitive

knowledge, and it can go beyond understanding, creating a sense of insecurity for inexperienced consumers.

The role of labels in choosing a wine from specialized stores.

Wine bottle as packaging, must meet three basic conditions at the sales shelf. The first condition is that it must attract the attention of the consumer who looks at the wine rack and ensure that a particular brand stands out from the entire range of alternative products. As a result, the most important tool for a manufacturer is the packaging to highlight its product of other available products offered on the shelf for sale.

In addition, the design forms are attractive to wine consumers. We buy a certain brand of wine based on “art, imaging and branding” (2012, Elliot and Barth).

Women's wine consumers are more influenced by design factors than men (2012, Bernabeu et al.). In fact, the label design compensates for the incomplete spaces on wine bottles/tags for a complete and artistic description of the taste. Wines label colours, which are extrinsic indications of the products and affect consumer expectations, for example, on flavour. In other expression, this research elaborates the hypothesis that, consumers can express opinions on certain characteristics of wines (flavours) based on the colours used to design label put on wine bottles. Links between different sensory peculiarities and associations between taste and colour have been demonstrated. Consumers are attracted to the figures, appearance and colour used in labels and help these particularities to infer the quality of the wine and brand personality.

The second most important predictor is the label, and this can decide the intention to buy wine, by price. Old traditional labels, such as those describing wine regions, pastel-coloured landscapes, assume good and high quality wines. Can be a contradiction with the effort made by traditional winemakers, appreciated from European and in the new world, which must research in label design by switching from these models and conventional motifs into "modern", appealing, colour rich pictures.

2. MATERIALS AND METHODS

As there is no specialist support for the sale of wines, especially in big markets, wine labels are the essential source for the consumers to obtain the information. As a result, it is the color of the label that greatly affects consumers in the buying of wine.

The aim of the paper is highlighting the correlation between the sensory experience and the colors of wine bottle labels. We can also discover differences in consumer behavior depending on the density of wine buying and gender.

The research result show that label colors have an important influence on wine flavor associations. Example, red wines, orange wine, rose, are associated with fruit and flower flavors. As a result, this can be considered by wine producers in framing their label to create sensory experiences according to the real flavor of their wine, which is, and they must match the expectations of the consumer when tasting the wines. It is especially important when the wine is sold in specialty market, and consumers are not able to rely on their taste experience before purchase.

The results of this work come with the aid of wine producers to efficiently design their labels. In that case, both the theoretical contributions and the strategic perspectives that this research offers to wine producers and traders are relevant.

The connection between the consumer and the product has an important role in the purchase intention. This is because packaging is no longer a simple tool, but has become a decision-maker for establishing a close relationship with the consumer. Glassware comes, and especially the main label of the bottle, is decisive not only for the transmission of information about the product as such, but also for the connection and involvement with the emotions and expectations of the consumer.

A sample by 60 people (45% women and 55% men) was studied in a specialized wine shop, for 5 minutes in front of a shelf with 50 bottles of wine, regarding the behavior connected to the information written on the labels of wine bottles, namely the name of origin and values of nutrition. One of the results of these observations is the hearty model for the desire to purchase, where the included components are explained by a specialist, but also the fact that consumers appreciate this information differently.

For consumer of the wine, buying a wine from a specialized store is not an easy task, given its large variety. as a result, the quality, the, the design and information included on the wine bottle labels are very

useful at the time of choice. Some specialists hypothesized that wine labels play a significant indicator in the choice of consumer products. That influences the expectations and emotional responses and generate changes in acceptability.

Regarding analysis of the sample by gender, it was found that women are attracted more by the nutritional information and the association of wines with food other than men. As a result, they show a greater interest in purchasing based on these values and we can say that there are difference between the male consumer and the female consumer. That is because men and women using different selectivity models to process information.

Women using more complete, selective model than men (Goodrich, 2014). In addition, women can read more carefully than men (Leong and Hawamdeh, 1999), have a bigger tendence to explore product information, because they want to find more about its contents (2016, Shaouf et al.; 2018, Aschemann-Witzel et al.).

Elaborate Hypothesis:

Hypothesis 1. Information on the designation of origin, the year of bottling and the way of association of wines have a positive influence and increase the purchase intention for both women and men.

Hypothesis 2. The inclusion of nutritional information has a greater influence on female consumers.

The study highlights that the female consumer, when purchasing a bottle of wine, is considering both nutritional information, combined with the appearance of the label and information related to the association of wine with food, while the male consumer is less visual and more interested in the designation of origin, year of bottling and alcohol content.

The study also develops empirical analyze, using a small part of the publicity but which can influence/help the consumer's decision when buying a bottle of wine.

The type of glass and its color must attract attention and help potential buyers to know and differentiate wines according to quality.

A good, quality wine can be enjoyed and appreciated over the years, only if clear storage rules are observed. The most important factor is light and as a result the wine should not be exposed to light. It does not love light, and the most sensitive wines are white and pink. Most of them are bottled in clear bottles. From this perspective, red wine is more of a long race, often bottled in green or brown bottles that protect from light or UV rays. Although it is not a written rule, wine producers choose the color of the bottle more from marketing reasoning. For a white or rose wine, a transparent bottle is often chosen to highlight the shade and texture of the wine. But there are wine collectors, who also bottled white wine in bottles of an ancient green shade, just to protect it from light.

The year of production.

It is much more useful to know the year itself passed on the label, or on the counter-label (on the back of the bottle), than knowing whether that year was a "good year" or a "bad year". What do you need to know about the year of production?

The younger a wine is, the more likely it is to be dominated by a fruity smell and taste. Young wines are characterized by fresh fruit flavors and the younger it is, the more likely it is to be unbarred (it is not aged in oak barrels - barrique). It is also likely that these wines are less full-bodied, more invigorating, and more affordable. Wines older than two years (except those forgotten by the stocks of a hypermarket) are usually premium wines, refined by aging, sometimes even barricaded. Mature wines are characterized by less fresh, but more complex and revealed flavors in stages/layers, often with distinctive baryl accents. These wines are usually more corpulent, more opulent, and more expensive.

Sometimes the purchase decision is influenced by the price. In wine, as in other consumer products, higher prices are involuntarily associated with high quality and vice versa. It's not always true. If we can economically justify the price structure for a premium wine, more expensive and we know that it consists of: quality grapes, select - with all the associated costs, winemaking, winemaking, aging (oak barrels, change to a maximum of 3 years), bottling, logistics, distribution, brand, marketing, etc., it is not as simple to find the logic for a very cheap wine, which gives rise to a series of questions about the quality of that product, perhaps unreasonably cheap.

If we also refer to the movement of the eyes during the buying process, we can say that the alerts paid to a bottle is decisive for the purchasing intention of consumers, as well, and this attention is growing in importance for prize bottles and when consumers buy wine for a consumer condition involving a social environment.

The results show a strong desire for the most typical label. Obviously, this preference decreases when the risk to consumption is associated with the quantity. For some consumer occasions understood to be less risky, respondents seem more open to choosing labels with a moderately atypical design.

Acceptance of atypical design is related to the level of risk perceived at the time of purchase. A commercial brand that targets consumer occasions that are perceived as less risky will, as a result, be able to move away more easily from the visual factors of its product category.

In addition, consumers are looking for experiences, and then their emotions intervene, and stories help create such experiences. At the same time, it can be said that stories are essential for how people need information and how people start to communicate with one another.

As a result, wine brands decided to tell stories related to their history because the story makes positive feelings in customers and is considered more convincing than facts. That can have more positive effects, such as increasing confidence in the mark. Brand stories have also can help the consumers better to differentiate the brand from competition.

The information is valuable for wine shops but also for experts or wine producers as they need to be able to combine different types of information to influence the purchase decision.

3. CONCLUSIONS

One of the challenges of this study is combining these results with research techniques related to neuroscience, engaging, and activating senses such as smell or taste at the point of sale. This gives the possibility of future research, as it could complement the results obtained and the combination of the results will be of scientific interest. This article presents importance to wine specialists, experts, research, as a starting point in understanding information about consumers behavior for the same products and markets. They can be used as a guide to identify similarities in consumer behaviors for different products with wine-like features.

We aim to complement this research with recent findings and conclusions related to consumer behavior by studying culture and noting differences in the country, culture, religions or races in wine consumption.

They can be used as a guide to identify similarities in consumer behaviors for different products with wine-like features.

A new research hypothesis must also be developed that nutritional information generate higher consumption, as in the case of wine, does not discourage consumption, rather but it increases the intention of buying this product. This factor can be compared with other alcoholic products to find out if the effect is the same.

A challenge is also for wine producers to develop wine tourism, the marketing of wine-related activities and the wine production process. That can be the perfect opportunity for entrepreneurs to have more expert consumers and educate the consumer in manner to distinguish the characteristics of good wine.

Wine is perhaps one of the most difficult to buy products, thanks to the extremely rich offer, both in stores and in restaurants. However, given a few simple rules, you can remove doubt and gradually increase your confidence in your own knowledge. Label finally do not tell us what the wine will taste like, but there are many things that we can discover between the lines.

Regarding the connection between the color of the packaging and the color of the wine, Rocchi and Stefani (2005) found that people re-read in two fundamental ways. In the first way, the consumers seem to be affected by the shapes, size, and colour of the bottle, while in the second way they consider the label of the bottle and the information on it. Some specialists show that color is the first level of perception and is used by respondents to emphasize differences of opinion and to express their preferences. These shapes and sizes of the bottle are also appreciated by consumers and are important features to consider.

This paper aims to define consumer preferences related to the colors and shapes used in wine labels design based on the responses of an empirical survey. It is also based on an elaborated empirical literature that reveals the powerful effects of label design on consumer perceptions of brand quality and personality.

As a first conclusion, color alone does not generate preferences as strong as the labels and information included on these, at least when they are evaluated regardless of the form that dominates the composition of the label.

More of framing and designing their labels based on their own style and taste, wine producers need to understand the meaning that the fonts, the colors, their shape in the minds of people. Because is a very competitive environment, such as the one faced by wine producers today, the choice of labels and the use of their own information and signifiers are appreciated by consumers, and that would allow producers to get closer to them.

4. REFERENCES

- [1] Barber, N., B.A. Almanza and Donovan, J.R. (2006). Motivational factors of gender, income and age on selecting a bottle of wine, *International Journal of Wine Marketing*, Vol. 18, No. 3, pp. 218–232.
- [2] Dr Art Thomas, Dr Gary Pickering. *International Journal of Wine Marketing*. ISSN: 0954-754, 2003
- [3] Lockshin, L. (2003). Consumer purchasing behavior for wine: what we know and where we are, *Marchés et Marketing du Vin*, No. 1, pp. 1–30.
- [4] Masson, J., Aurier, P. and d'hauteville, F. (2008), "Effects of non-sensory cues on perceived quality: the case of low-alcohol wine", *International Journal of Wine Business Research*, Vol. 20 No. 3, pp. 215-229.
- [5] Nomisma (2003), *Wine marketing. Il Marketing del vino in Europa: consume, canali, distributori e importatori*, Agra Editrice, Roma.
- [6] Pitta, D. (2007). Building brand equity and share of heart at Nassau Valley Vineyards, *Journal of Product and Brand Management*, Vol. 16, No. 2, pp. 148–151.
- [7] Renaud Lunardo, Bradley Rickard. *British Food Journal*. ISSN: 0007-070X, 2019
- [8] Rocchi, B. and Stefani, G. (2005). Consumer's perception of wine packaging: a case study, *International Journal of Wine Marketing*, Vol. 18, No.1, pp. 33–44.
- [9] Thomas, A. and Pickering, G. (2003), "The Importance of Wine Label Information", *International Journal of Wine Marketing*, Vol. 15 No. 2, pp. 58-74.
- [10] Westerman, S. J., Sutherland, E. J., Gardner, P. H., Baig, N., Critchley, C., Hickey, C., Mehigan, S., Solway, A., & Zervos, Z. (2013). The design of consumer packaging: Effects of manipulation of shape, orientation, and alignment of graphical forms on consumers' assessments. *Food Quality and Preference*, 27, 8-17.

RESEARCH ON SOME BIOLOGICAL AND TECHNOLOGICAL ASPECTS OF THE SPECIES HYACINTHUS ORIENTALIS (FAM. LILIACEAE)

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Abstract

In a vase or in a pot, in a bouquet or in an arrangement, in the house, in the garden or in the park, alone or in combination, flowers are just as many occasions of joy that we give to ourselves or to our loved ones. Messengers of human thoughts and feelings, flowers contribute to the development of social relations, reflecting in the most brilliant way the refinement, taste and personality of man. Some authors expand the area of use of some of the flowers in the food sphere, considering them edible flowers. However, flowers mean, above all, love, love, hope, trust, appreciation, lust for life; through them we express everything that is noblest and most beautiful in the life of each of us. It is certain that if each of us understood - even just for a moment - the extraordinary message that a flower so eloquently conveys, then the world we live in would be much better. Flower culture at a high technological level cannot be done without thorough knowledge of biology, plant physiology and ecology, genetics and plant breeding, agrochemistry, pedology, agrotechnics, phytopathology and entomology, and for the commercialization of production and ensuring economic profitability, it is also necessary marketing knowledge and market research. Knowing the biological properties of plants and their reaction to different environmental conditions and agrotechnical works are essential in the design and application of a high-performance technology. The mastery of this information in the sphere of the disciplines mentioned above denotes a high qualification of the florist specialist and the satisfaction of successful crops is possible only by doubling this qualification with intense work, done with a lot of passion and dedication.

Keywords: hyacinth, vegetative organs, floral organs

1. INTRODUCTION

The greenhouse is established in Uliești commune, Croitori village, Dâmbovița county. The climate of Dâmbovița County is continental - moderate with differences in the hill and forest area and in the mountain area. The county's climate has the following characteristics: hot summers and long, cold winters. In the western part of the county, the climate has more arid nuances, summers being generally drier and warmer.

Average annual temperatures (table 1) are between 1°- 5 °C in the eastern part and 7°-10 °C in the western part, the month with the highest temperatures being July with 20°- 22 °C, and the one with the lowest temperatures in January with -4°- 4 °C. The relative humidity of the air is also a factor to be considered, so it has been covered in table 1. Although the greenhouses are equipped with their own heating, it is very important to know these temperatures that have been recorded during these years. Water is an important vegetation factor which, through its role in the unfolding of vital processes, is indispensable in the life of plants. Precipitation is the main source of water supply. These are in the atmosphere as rain or snow.

More abundant precipitation favors the growth and development of the plant. Also, the average duration of the snowfall interval is 50 - 100 days/year, but it can reach 130 days in the higher areas.

The duration of the sun's shine can influence the way the biochemical and physiological processes in the plants unfold, but also the loss of water from the soil and the plant.

Solar radiation is the main source of energy that provides the heat necessary for the growth and development of plants. In solariums, sometimes the daily radiation values can be deficient, namely, the areas with lower potential in the years with a shorter duration of sunshine and especially in the months of November, December and January.

The values are influenced by the covering materials of solariums or culture shelters, which have a different transmission coefficient (0.8 for glass, 0.7 for polyethylene and 0.6 - 0.65 for polyvinyl chloride), over time the initial transparency of the covering materials decreases by 20 - 30% as a result of the deposition of dust, smoke or snow.

Aeolian regime

The predominant winds are west and northwest, with an intensity of 3.8 m/s and a frequency of 12.9%. Winds from the South have the lowest weight (table 4).

For forced crops, knowing the intensity and direction of the winds is of particular importance because cold winds cause significant heat loss from inside the greenhouse, through convection.

2. MATERIALS AND METHODS

The *Hyacinthus orientalis* plants that constituted the material for the study of the biological and technological particularities belong to our own greenhouses.

From the *Hyacinthus* batch, 3 varieties of the "*Hyacinthus orientalis*" species were studied, 10 plants were chosen from each variety, 30 plants being analyzed in total. These observations were made during the 3 repetitions.

Plants were chosen that met the characteristics of the variety as faithfully as possible, because the studies carried out followed some biological and technological characteristics of the species. A set of biometric measurements and observations on those characteristics of plants that are directly related to their quality, such as: number of shoots, plant height, flower stalk length, flower length, flower diameter, number of flowers on the floral stem, and the duration of storage in water. Thus, we tried to find the best variety in terms of quality and to last as long as possible by keeping the minimum conditions, because they are popular both in pots, as cut flowers in bouquets, or floral arrangements, and planted in the garden.

Following the research and measurements carried out, it was found that within the varieties studied, the storage time of cut flowers is between 8 and 12 days, the height of the plants can reach up to 40 cm, and the number of flowers on the flower stalk is between 8 and it can go up to 23.

It should be noted that these observations and measurements were made during the first flower harvest. It was necessary to make the set of observations during the first harvest, because in the greenhouse we put other flowers depending on the season.

Following the researchers, it was found that only one flower stem grows on the plant. It could also be observed that the flowers open successively on the floral stem.

The cultivation technology applied to this Hyacinthus crop was that for planting in greenhouses and solariums and all the steps were followed to obtain a crop as productive as possible, but at the same time that does not involve very high costs. The plants were grown by sowing directly in the soil, in furrows and in pots.



Figure 1. Preparation for planting



Figure 2. Garden soil

The soil mixture for this crop consisted of garden soil, peat and perlite. To begin with, basic fertilization was done with superphosphate and magnesium sulfate.

The planting distance was 15 cm between rows and 15 cm between plants per row. Watering was done by sprinkling until the seedlings were caught, after which it was switched to drip irrigation, until flowering. Fertilization with chemical fertilizers took place weekly with nitrogen, potassium and calcium.



Figure 3. Peat



Figure 4. Perlite

Description of varieties

Hyacinthus Orientalis Blue Jacket is a perennial bulbous plant that is part of the *Liliaceae* family.

Hyacinthus Orientalis Blue Jacket is an intense blue variety, extremely fragrant. The colors fade and blend as the flower develops. Flowering takes place in the middle of spring, for 2 - 3 weeks. Height at maturity 20 - 30 cm. The stem is erect, vigorous, bright green, completely covered with flowers.

Hyacinths are extremely popular garden plants due to their wide assortment of colors and incredible smells. Superb spring flowers, of a special naturalness, which, despite their simplicity, attract the eye, evoking a feeling of peace and calm.



Figure 5. ***Blue Jacket*** bulbs

The flowering period of the Blue Hyacinth is in the months of April and May. This flower has an easy growth. The places it prefers and where it develops best are places with a lot of light and sun. The soils in which Blue Hyacinth grows best are well-drained, moist and fertile soils.

Hyacinthus Blue Jacket is a very decorative flowering plant and appreciated due to its beautiful appearance and due to the fragrance, it emits. The blue hyacinth is an ornamental plant for the garden, but it can also be planted in pots to decorate rooms and homes.



Figure 6. ***Blue Jacket*** hyacinth

Pink Pearl hyacinth

Common name: ***Hyacinth***.

Scientific name: ***Hyacinthus Orientalis 'Pink Pearl'***.

Pink Pearl hyacinth is a perennial garden plant with good resistance to winter cold. In other words, viola bulbs should not be taken out of the ground in the fall, before frost. The cold of winter is a necessary stage for good flowering the following year.

Pink Pearl hyacinth bulbs are easy to propagate.

It also does well in the sun, but also in semi-shaded areas. The ***Pink Pearl*** hyacinth is distinguished by its large, light pink, fragrant flowers.

One should plant ***Pink Pearl*** hyacinth bulbs in autumn, at a depth of 10-15 cm as the bulbs are quite large.



Figure 7. ***Pink Pearl*** hyacinth

Depending on the weather, the ***Pink Pearl*** hyacinth will bloom between April and May.

Pink Pearl hyacinth characteristics may vary depending on sun exposure, time of planting, moisture level, fertilizers, soil type, maintenance performed, pests, and other factors.

White Pearl hyacinth

The dense flowers, grown in bunches, are appreciated both for their tender appearance and their sweet scent. Hyacinths were cultivated on the old continent from the second half of the 16th century, but they became famous in the 18th-19th centuries.



Figure 8. ***White Pearl*** hyacinth

Essential for a well-developed plant with a large inflorescence is to have large bulbs. Plant them in pots at least 11 cm in diameter and more than 20 cm deep. Hyacinth bulbs are planted about 15 cm deep and need a substrate of 6-7 cm.

There must also be a drainage layer (gravelly sand) up to the bottom of the pot. It is recommended that the pots have holes in the bottom. Good drainage is very important for potted bulb plants.

Variants and working method

Hyacinthus cultivation technology involves several aspects compared to other flower crops. Interventions on the plants must be done with care by those who perform them, the culture also requiring a great finesse and specialization of it. These characteristics are due to the fragility of the flower stems, which can break very easily. For this reason, in this work, a special emphasis was placed on the biology of hyacinths, on their behavior and response to general technological measures. The applied technology was in great accordance with the delivery possibilities and market requirements and the environmental conditions characteristic of the area. The observations made on the batch of flowers followed their response to the conditions encountered during the execution of the study for the preparation of the diploma project. The present paper aims to highlight the biological aspects of the plant and the observed technology and formulate conclusions and recommendations that could help to improve the *Hyacinthus orientalis* genus. Observations were made on 30 plants of each variety, 90 plants in total, each being individually numbered. Of the 90 plants, 30 were white, 30 pink and 30 blue. These researches were carried out over a period of two years, from 2019 to 2021, during which all stages were followed to obtain the *Hyacinthus* culture. By analyzing the data obtained from each of the 30 plants taken into analysis, from each variety, their average was performed, being later analyzed with the help of the "t" test to highlight the possible differences between the three varieties regarding the observed characters.

Observations and determinations

The observations and determinations made were centralized in 2 main directions, namely:

- a.) Biology of vegetative organs;
- b.) Biology of floral organs and their relationship with vegetative organs; Regarding the biology of the vegetative organs, the leaf was particularly studied, and in the case of the biology of the floral organs, the flower itself and the floral stems of which it is a part were studied.

3. RESULTS AND DISCUSSIONS

In order to be able to thoroughly describe the material that was worked with and also to check the agreement between the general data and those obtained from the research, certain observations and biometric measurements were made on the most important characters of the plant, on which the quality of the flowers depends. Thus, the following were determined: the height of the plant, the length of the floral stem, the length of the flower, the number of flowers on the floral stem, the color of the petals and the storage time as cut flowers in water. Through this work, the aim was to determine the variety with the best quality of flowers, but also the one that presents as faithfully as possible the general characteristics of *Hyacinthus* cultures.

Observations and determinations on the plant

In order to obtain determinations on the plant, the following were taken into account: the height of the plant, the length of the floral stem and the color of the flowers to help distinguish the varieties between them.

The height of the plant

For plant height, measurements were made on the 30 plants of each variety, then their arithmetic mean was calculated. The obtained data were noted in the table below and calculated according to the limit difference method. These data were interpreted as follows:

Table 1. Morphological determinations regarding plant height

Variety	Plant height		Difference (±cm.)
	Absolute (cm.)	Relative (%)	
„Blue Jacket ”	40,00	85,25	- 8,00
„Pink Pearl ”	37,00	102,74	+ 1,00
„White Pearl”	34,00	113,03	+ 9,00
Average (Mt)	37,00	100	

DL 5% = 2,45 DL 1% = 5,65 DL 0,01% = 8,55

Regarding the height of the plant, it varies between the limits of 40.00 cm for the "Blue Jacket" variety and 34.00 cm for the "White Pearl" variety.

Analyzing the average of the 3 we can see that there are varieties with a shorter length, namely the variety "White Pearl" (34.00 cm.). From a statistical point of view, regarding the height of the plant, following the observations made, a distinctly significant positive difference was found in the "White Pearl" variety, a very significant negative difference in the "Blue Jacket" variety, and an insignificant difference in the "Pink Pearl" variety compared to the average of the varieties, considered as a control.

The length of the flower stem

Regarding the length of the floral stem, this is a very important character, which was observed in the 3 varieties. The results thus obtained are presented in table 2.

Table 2. Determinations of the length of the floral stem

Variety	Length of floral stem		Difference (±)
	absolute (cm.)	relative (%)	
„Blue Jacket ”	30,00	112,50	+ 5,00
„Pink Pearl ”	25,00	105,00	+ 2,00
„White Pearl”	28,00	82,50	- 7,00
Average (Mt)	28,00	100	

DL 5% = 0,25 DL 1% = 3,42 DL 0,01% = 6,22

It can be observed from the research carried out, that this analyzed character varies between the limits of 30.00 cm for the "Blue Jacket" variety and 25.00 cm for the "Pink Pearl" variety. Taking the average of the character 28.00 cm and analyzing the other variants, we can see that in the variety "Pink Pearl" it is smaller than the average. From a statistical point of view, regarding the length of the floral stem, the "White Pearl" variety presents a very negative significant difference, the "Blue Jacket" variety has a significantly positive difference, and the "Pink Pearl" variety presents a distinctly significant positive difference, compared to the average varieties, considered as a witness.

The color of the petals

Regarding the color of the petals, the 3 varieties can be distinguished very easily from this point of view, because all 3 varieties have a different color of the petals. These colors are highlighted in table 3.

Table 3. Petal color determinations

Variety	Petal colour
„Blue Jacket ”	blue
„Pink Pearl ”	pink
„White Pearl”	pure white

Analyzing table 3., the white (White Pearl), pink (Pink Pearl) and pure white (Blue Jacket) varieties stand out.

Observations and determinations on the flower

Flower length

Regarding the length of the flower, measurements were made to observe the variety with the largest flowers. The data thus obtained are presented in table 4, which will be interpreted from a statistical point of view.

Table 4. Determinations of flower length

Variety	Flower length		Difference (±)
	absolute (cm.)	relative (%)	
„Blue Jacket”	1,50	78,32	-1,66
„Pink Pearl”	2,50	104,44	+0,34
„White Pearl”	3,00	117,49	+1,34
Average (Mt)	2,33	100	

DL 5% = 0,48 DL 1% = 1,16 DL 0,01% = 1,59

From a statistical point of view, it was observed that in the case of the "Blue Jacket" variety, there is a very significantly negative difference, in the case of the "Pink Pearl" variety, the difference is insignificantly positive, and in the case of the "White Pearl" variety, a distinctly significant positive difference is observed.

The diameter of the flower

In the case of the diameter of the flower, the data obtained from the measurements carried out, they were presented in table 5. These data are as important as those related to the length of the flower, so that in the end we can find out which variety has bigger flowers.

The data thus obtained were also statistically interpreted.

Table 5. Determinations made on the diameter of the flower

Variety	Flower diameter		Difference (±)
	absolute (cm.)	relative (%)	
„Blue Jacket ”	1,00	78,99	-1,33
„Pink Pearl ”	2,00	94,79	-0,33
„White Pearl”	3,00	126,38	+1,67
Average (Mt)	2,00	100	

DL 5% = 0,43 DL 1% = 1,20 DL 0,01% = 2,18

From a statistical point of view, it follows that the "Blue Jacket" variety presents a distinctly significantly negative difference, while the "White Pearl" variety is distinctly significantly positive. Regarding the "Pink Pearl" variety, it shows insignificantly negative differences, compared to the average of the varieties, considered as a control.

The number of flowers on the flower stalk

This aspect is of particular importance, because it directly influences the quality of the flower, the more flowers the flower stem has, both open and in bud phase, the more the flower is appreciated by buyers. The data obtained as a result of the research were noted in table 6. and in this case the data being interpreted from a statistical point of view.

Table 6. Determinations made on the number of flowers on the floral stem

Variety	Number of flowers on the floral stem		Difference (±)
	absolute (cm.)	relative (%)	
„Blue Jacket”	18,00	71,80	-3,30
„Pink Pearl”	24,00	122,89	+2,70
„White Pearl”	32,00	107,19	+0,70
Average (Mt)	24,66	100	

DL 5% = 0,36 DL 1% = 1,89 DL 0,01% = 3,17

Following statistical research, a very significantly negative difference was observed in the "Blue Jacket" variety, a distinctly significant positive difference in the "Pink Pearl" variety, while the "White Pearl" variety shows a significantly positive difference, compared to the control.

The number of petals

Considering the number of petals of a flower, they are usually 5, the flower being type 5, but following some hybridizations, breeders managed to form varieties that have more than 5 petals. The research data from this point of view were exposed in table 7.

Table 7. Observations made regarding the number of petals

Variety	Number of petals		Difference (±)
	absolute (pcs.)	relative (%)	
„Blue Jacket”	5	75,76	-1,6
„Pink Pearl”	5	75,76	-1,6
„White Pearl”	6	101,51	+2,4
Average (Mt)	5,33	100	

DL 5% = 1,99 DL 1% = 3,58 DL 0,01% = 5,63

As a statistical interpretation following the research carried out on the number of petals, it can be observed that the "Blue Jacket" and "Pink Pearl" varieties show insignificantly negative differences, and the "White Pearl" variety is significantly positive, compared to the average of the varieties, considered as a control.

Storage time duration

Regarding the duration of storage in water, we can say that it is a highly sought-after aspect by buyers, because the longer the duration of storage, the more appreciated the flowers are. Determining the shelf life of cut flowers was carried out by keeping them in plain water, without the addition of preservatives, in order to establish these data under the conditions that can be met by any of the buyers. The data thus obtained are presented in table 8.

Table 8. Determinations of storage time duration of cut flowers in water

Variety	Storage time duration of cut flowers in water		Difference (±)
	absolute (days)	relative (%)	
„Blue Jacket”	10,00	83,33	-2,00
„Pink Pearl”	12,00	100,00	0
„White Pearl”	14,00	116,66	2,00
Average (Mt)	12,00	100	

DL 5% = 1,29 DL 1% = 4,52 DL 0,01% = 7,31

From a statistical point of view, distinctly significant positive differences were observed in the "*White Pearl*" variety, negative in "*Pink Pearl*" and an insignificant difference in the "*Blue Jacket*" variety.

Aspects from the culture





4. CONCLUSIONS

Following the research carried out on the main morpho-decorative characters of the 3 varieties of *Hyacinthus orientalis* taken in the study, the following conclusions are noted:

- under the aspect of plant height, the variety "*Blue Jacket*" can be particularly noted, which recorded a height of 40 cm, unlike "*White Pearl*" which recorded only 34 cm;
- with regard to the length of the floral stem, the variety "*Blue Jacket*" is also noteworthy with a length of 40 cm, unlike "*White Pearl*" with a length of 34 cm;
- the variety "*White Pearl*" stands out, in terms of the diameter of the flower (3 cm) and the length of the flower (3.5 cm), unlike, again, the variety "*Blue Jacket*" which has a diameter of 1 cm and a length of 1.50 cm;

- regarding the number of flowers and storage time, the highest performances were found in the "*White Pearl*" variety, unlike the "*Blue Jacket*" and "*Pink Pearl*" variety. Following the conclusions listed above, it can be said that the variety "*Blue Jacket*" is not a variety of the best quality, it fails to excel in any of the observations made, although it is one of the most cultivated varieties, because it still manages to attract with the beautiful coloring of the petals (white with dark purple edges).

Although the variety '*White Pearl*' has the largest flowers in size, it does not have as many flowers as the variety '*Pink Pearl*', which also manages to keep as a cut for about 14 days.

One of the most important recommendations is the introduction into the assortment of varieties that present many flowers on the floral stem, large and with as long a storage time as possible in minimal conditions.

Improving the assortment of cut flowers, with new varieties of *Hyacinthus*, with superior morpho-decorative qualities is a concern of traders, in order to obtain substantial incomes, therefore the varieties with superior qualities must be promoted in culture (*White Pearl* and *Blue Jacket*).

5. REFERENCES

- [1] Ardelean M., Sestraš R., Cordea M., 2007, „Tehnică experimentală horticolă”, Ed. AcademicPres, Cluj-Napoca;
- [2] Băla Maria, 1998, „Floricultură generală”, Ed. Mirton, Timișoara;
- [3] Băla Maria, 2003, „Floricultură specială”, Ediția a II-a, Ed. Timpolis, Timișoara;
- [4] Cantor Maria, 2003, „Floricultură generală și specială”, Ed. Risoprint, Cluj-Napoca;
- [5] Cantor Maria, Pop Ioana, 2008, „Floricultură – Bază de date”, Ed. Todesco, Cluj-Napoca;
- [6] Cantor Maria, 2009, „Floricultură generală”, Ed. Todesco, Cluj-Napoca;
- [7] Ghizdavu Iustin, 2004, „Entomologie agricolă specială. Dăunători polifagi”, Ed. AcademicPres, Cluj-Napoca;
- [8] Jidav L., Sonea V., 2002, „Mica enciclopedie de horticultură”, Ed. Științifică și Enciclopedică, București;
- [9] Kiselev, G. E., 1956, „Floricultură”, Ed. Agrosilvică, București;
- [10] Marinescu Gh și colab., 1988, „Bolile plantelor floricole”, Ed. Ceres, București;
- [11] Nicu Carmen, Doina Anton, Manuela Manda, 2007, „Floricultură specială”, Volumul 2, Ed. Universitară;
- [12] Oroian Ioan, Puia Carmen, Șerba Ioan, 2002, „Practicum de fitopatologie”, Ed. Poliam, Cluj-Napoca;
- [13] Preda M., 1980, „Floricultură”, Ed. Didactică și Pedagogică, București;
- [14] Preda M., 1989, „Dicționar dendrofloricol”, Ed. Științifică și Enciclopedică, București;
- [15] Sonea V. și colab., 1979, „Floricultură”, EPD București.

THE ANNALS OF “VALAHIA” UNIVERSITY OF TARGOVISTE
2024

Average temperatures recorded between 2019 – 2021

Month Year	1	2	3	4	5	6	7	8	9	10	11	12	Annual average
2019	-5,5	-1,9	1,3	10,1	16,8	17,3	17,7	20,6	13,8	8,8	3,2	-1,0	9,8
2020	1,9	3,2	2,2	11,0	15,2	14,6	20,4	19,2	14,7	9,6	4,7	2,1	9,9
2021	4,8	2,4	7,5	9,7	14,3	19,1	19,9	24,3	20,5	11,2	6,3	5,4	12,1
Monthly average	4,0	2,5	3,6	10,2	15,4	17,0	19,3	21,3	16,3	9,8	4,7	2,8	

Average precipitation recorded between 2019 - 2021

Month Year	1	2	3	4	5	6	7	8	9	10	11	12	Annual average
2019	1,0	13,2	23,2	10,6	34,0	46,4	62,4	9,0	37,8	28,2	58,0	41,6	30,4
2020	8,6	14,6	3,0	42,2	35,6	67,8	116,0	56,6	46,8	39,8	47,6	19,8	41,5
2021	0,0	0,2	5,4	20,0	83,6	165,6	29,4	0,8	0,0	0,0	6,0	9,6	26,6
Monthly average	3,6	9,33	10,5	24,2	51,1	93,3	69,2	23,9	28,2	22,6	37,2	23,7	

The relative humidity recorded between 2019 – 2021

Month Year	1	2	3	4	5	6	7	8	9	10	11	12	Annual average
2019	88,1	82,7	67,9	68,3	72,5	69,5	75,9	80,5	81,1	82,3	91,8	88,5	79.09
2020	82,7	76,7	65,3	62,0	64,1	66,7	69,8	69,2	65,5	72,7	75,3	81,6	70,96
2021	93,5	90,3	71,5	71,5	76,7	73,6	82,6	86,6	85,4	86,2	88,9	93,5	83.34
Monthly average	88,1	83,3	68,2	67,2	71,1	69,9	76,1	78,7	77,3	80,4	85,3	87,8	

REVIEWING THE ROLE OF FUNCTIONAL INGREDIENTS IN IMPROVING IMMUNE HEALTH AND DISEASE MANAGEMENT IN BREEDING ANIMALS: CURRENT PERSPECTIVES AND EMERGING TRENDS

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Abstract

This review delves into recent advancements in livestock research, focusing on genetic diversity, disease resistance, and immune function. Through an in-depth analysis of various studies, this review elucidates the intricate interplay of genetic factors influencing disease susceptibility and resilience in livestock populations. Investigations highlight the efficacy of functional ingredients, such as plant extracts and marine-derived compounds, in enhancing immune health and disease resistance in breeding animals. Additionally, the review examines the molecular mechanisms underlying the immunomodulatory effects of specific ingredients, shedding light on signaling pathways and gene expression profiles involved in bolstering immune function. Furthermore, the review explores emerging trends in livestock nutrition, including the utilization of fruit processing by-products to improve animal health and performance. Insights into the role of prebiotics in modulating gut microbiota and mitigating diet-related maladies provide valuable perspectives for enhancing livestock welfare and productivity. By synthesizing these findings, this review underscores the critical importance of genetic selection, dietary interventions, and immunomodulatory strategies in promoting the health and resilience of livestock populations.

Keywords: disease resistance, immune function, functional ingredients, gut microbiota

1. INTRODUCTION

The immune function and disease resistance in breeding animals are paramount for ensuring their health, welfare, and productivity. Genetic and genomic techniques have been pivotal in elucidating the intricate mechanisms underlying disease resistance, interpreting data, and leveraging research outcomes to breed animals with enhanced resistance [1]. For instance, studies have revealed the influence of genetic diversity among cattle breeds on susceptibility to diseases like bovine tuberculosis, underscoring the genetic underpinnings of disease resistance [2,3]. Moreover, innate immune genes, such as Toll-like receptors, play a pivotal role in cattle immune systems, further highlighting the genetic basis of disease resistance [4].

Selective breeding for disease resistance has gained prominence in aquaculture breeding programs, particularly in species such as Atlantic salmon and rainbow trout, thus emphasizing the criticality of genetic evaluation for disease resistance in aquaculture species [5]. Furthermore, understanding the genetic footprints of cattle breeds has been instrumental in elucidating their disease resistance and genetic contributions, thereby accentuating the necessity to consider breed characteristics in disease resistance strategies [6,7]. Notably, genetic variations in specific genes like SLC11A1 and TLR2 have been associated with resistance to bovine tuberculosis and other diseases in cattle,

offering insights for selective breeding of disease-tolerant animals [8,9,10]

The identification of major quantitative trait loci related to innate mechanisms has furnished invaluable insights into the genetic foundation of disease resistance in rainbow trout, paving the way for discerning the genes responsible for resistance to specific diseases [11]. Additionally, the advent of precise genome editing holds promise in augmenting animal disease resistance, production efficiency, and welfare, thereby underscoring the role of advanced genetic technologies in enhancing disease resistance [12]. Furthermore, the evaluation of genetic variations and selection of animals based on resistance genes are imperative for the implementation of disease resistance breeding programs in small ruminant breeds, such as goats and sheep [13].

The immune system and genetic markers distinguishing between resistant and susceptible genotypes for specific diseases, such as Johne's disease, have been extensively studied in red deer, thus highlighting the influence of host genotype on disease susceptibility [14]. Moreover, the advent and dissemination of DNA-based diagnostics have significantly impacted animal breeding, health, and population management, underscoring the indispensability of genetic testing in disease management and breeding programs [15].

Functional ingredients play a pivotal role in enhancing immune health and disease resistance in breeding animals. These ingredients, derived from various sources, exhibit

promising potential in improving animal health and welfare. The use of functional ingredients in animal nutrition has garnered significant attention owing to their immunomodulatory effects and their ability to enhance disease resistance [16,17]. Additionally, the identification of potential biomarkers through advanced analytical techniques, such as mid-infrared spectrometry, offers avenues to discern the immunomodulatory effects of functional ingredients [18].

Furthermore, genetic studies have underscored the significance of functional ingredients in disease resistance, with a focus on the immunogenetics of small ruminant lentiviral infections and the selection of animals based on resistance genes for disease management [19,20]. The genetic diversity and innate immune genes among different cattle breeds have been associated with variations in disease resistance, thus accentuating the potential of genetic selection for improved disease resistance [1].

In addition to genetic factors, the immune response of animals to pathogens and parasites has been scrutinized concerning functional ingredients. For instance, the resistance of sheep to nematode infections has been correlated with variations in specific genes and immune responses, thereby shedding light on the potential role of functional ingredients in enhancing disease resistance [21,22]. Moreover, the utilization of functional ingredients in aquaculture has exhibited promise in augmenting disease resistance in fish species, with studies focusing on immune responses and genetic parameters associated with enhanced disease resistance [23]. The potential of functional ingredients in bolstering the immune responses of animals has also been probed in reptilian species, furnishing insights into the role of photoperiod and melatonin in modulating immune responses [24].

The aim of this comprehensive review article is to provide a thorough examination of the interplay between immune function, genetic factors, and the utilization of functional ingredients in enhancing disease resistance in breeding animals.

2. OVERVIEW OF IMMUNE FUNCTION IN BREEDING ANIMALS

The immune system of breeding animals encompasses pivotal constituents crucial for maintaining their health and bolstering disease resistance. Constituting a multifaceted network of cells, tissues, and organs, the immune system orchestrates a coordinated defence mechanism against pathogens and exogenous agents. Numerous investigations have illuminated the diverse facets of the immune system in breeding animals, offering invaluable insights into their genetic, cellular, and molecular underpinnings. Genetic inquiries have underscored the significance of immune-related genes and

their pivotal role in conferring disease resistance in breeding animals. Specifically, research has elucidated the crucial involvement of certain genes, notably major histocompatibility complex (MHC) genes, in orchestrating immune responses and fortifying resistance to diseases across vertebrates. Furthermore, the delineation of quantitative trait loci (QTL) associated with innate immune mechanisms has yielded profound insights into the genetic architecture underpinning disease resistance, thereby paving avenues for identifying pivotal genes governing resistance. The cellular and molecular constituents of the immune system in breeding animals have been subjected to extensive scrutiny in scientific discourse. Investigations have meticulously examined T lymphocyte subpopulations, including CD4+ and CD8+ T cells, and their genetic regulatory mechanisms in swine, thus underscoring the criticality of specific immune cell subsets in engendering disease resistance. Additionally, inquiries into the roles of distinct immune cells, such as leukocytes, in responding to environmental and breeding-related stimuli have furnished insights into the modulation of immune responses in breeding male ground squirrels. The immune system of breeding animals is further susceptible to seasonal and environmental influences. Empirical findings have delineated how seasonal variations can exert profound effects on immune responses and parasite impact on hosts, with individuals in peak condition exhibiting heightened immune reactivity during breeding periods. Moreover, investigations into the ramifications of shifting climatic conditions and burgeoning population densities have shed light on their interplay with immune function in Turkish native cattle breeds, thereby accentuating the imperative of adopting preemptive measures against potential risks. Disease resistance and immune function are intricately interwoven facets of the immune system in breeding animals. Studies have underscored the pivotal role of maintaining a harmonious immune responsiveness in breeding endeavors to ameliorate animal health, thus underscoring the necessity of integrating immune function as a cardinal consideration in breeding initiatives. Furthermore, the identification of immune-related genes and their allelic variations among disparate breeds has furnished profound insights into the genetic foundations of disease resistance and immune function in animals.

The ramifications of compromised immune function on animal health and productivity are intricate and have been extensively scrutinized. The immune system assumes a pivotal role in safeguarding animals against diseases and upholding their overall well-being. When immune function falters, it precipitates significant repercussions for animal health and productivity across diverse domains. Firstly, compromised immune function heightens susceptibility to infectious diseases, rendering animals more vulnerable to infections and ailments.

Empirical evidence has elucidated that animals with attenuated immune systems are at an elevated risk of contracting diseases, culminating in deleterious effects on their health and welfare [25,26]. Secondly, compromised immune function exerts adverse effects on animal productivity. Studies have underscored that animals grappling with compromised immune systems may encounter diminished growth rates, attenuated feed efficiency, and impaired reproductive performance, ultimately undermining overall productivity [27,28,29]. Thirdly, animals with compromised immune function may manifest signs of discomfort, subdued activity, and altered behavior, thereby impinging upon their welfare. The ramifications of compromised immune function on animal welfare have emerged as a burgeoning concern, given its potential to impinge upon the overall quality of life for the animals [30,31]. Moreover, environmental stressors such as heat stress can compromise immune function in animals, precipitating diminished productivity and health maladies. Seasonal vicissitudes and extreme meteorological conditions can further exacerbate the implications of compromised immune function on animal health and productivity [31,32]. Additionally, compromised immune function can precipitate metabolic stress, oxidative stress, and impaired nutrient absorption, thereby exerting profound impacts on animal health and productivity. Studies have underscored the intricate interplay between immune function, nutritional status, and metabolic processes in animals [33,34]. Furthermore, animals with compromised immune function may evince heightened susceptibility to the deleterious effects of toxins and pollutants, exacerbating health ailments and impeding productivity. The implications of compromised immune function vis-à-vis exposure to environmental contaminants constitute an emerging area of concern [35,36].

3. FUNCTIONAL INGREDIENTS AND THEIR MECHANISMS OF ACTION

Functional ingredients in animal nutrition encompass bioactive compounds, nutrients, or substances derived from various sources that confer additional health benefits beyond fundamental nutrition. They are integrated into animal diets to bolster immune function, advance overall health, and heighten disease resistance. Illustrative examples of frequently employed functional ingredients in animal nutrition include:

1. **Plant Feedstuffs:** Plant-derived ingredients like oilseeds, legumes, and cereal grains serve as functional ingredients in animal nutrition, providing protein, energy, and essential nutrients. Additionally, they may contain bioactive compounds that augment animal health and well-being.
2. **Algal Proteins:** Algal proteins are increasingly utilized as functional ingredients in animal nutrition, offering a sustainable and nutrient-rich reservoir of amino acids, vitamins, and minerals. Their incorporation contributes to enhanced animal health and performance [37].
3. **Soybean Molasses:** Employed as a functional feed ingredient, soybean molasses acts as a pelleting aid and imparts nutritional benefits, thus enhancing the overall quality of animal feed [38].
4. **Insect and Fish By-Products:** By-products sourced from insects and fish are harnessed as sustainable alternatives to traditional animal proteins in animal nutrition. These by-products furnish essential nutrients such as protein, fatty acids, and minerals, thereby fortifying animal health and well-being [39].
5. **Fucoxanthin:** Fucoxanthin, a functional ingredient with potential medicinal and nutritional attributes, is utilized in animal nutrition to confer antioxidant and anti-inflammatory properties, thereby augmenting health and disease resistance [40].
6. **Fruit and Vegetable Co-Products:** Residues generated from fruit and vegetable processing serve as functional feed ingredients in animal nutrition. These co-products confer nutritional value and contribute to enhanced animal performance [41].
7. **Plant Proteins:** Proteins derived from plants are integrated into animal nutrition as functional ingredients, providing essential amino acids and augmenting the overall protein content of animal diets [42].

These examples underscore the diverse repertoire of functional ingredients employed in animal nutrition to fortify immune health, bolster disease resistance, and improve the overall animal welfare.

4. EFFECTS OF FUNCTIONAL INGREDIENTS ON IMMUNE FUNCTION AND DISEASE RESISTANCE

The investigation into the impact of functional ingredients on immune parameters, encompassing cytokine production, antibody response, and phagocytic activity, has undergone extensive scrutiny within the scientific community. Studies have delved into the immunomodulatory effects of diverse functional ingredients, unraveling their potential in fortifying host defense mechanisms. Notably, research endeavors have elucidated the influence of vitamin A supplementation on immune responses and clinical outcomes, underscoring its role in bolstering antibody production and lymphocyte proliferation [43,44].

Furthermore, examinations into the immunomodulatory ramifications of various nutritional combinations have shed light on their effects on cytokine production and immune competence [45]. Additionally, investigations probing into the influence of functional ingredients on gut health and immunity have unveiled the modulation of immune responses through dietary components, elucidating intricate interactions therein [46].

Moreover, the exploration of specific functional ingredients, such as soybean products, has delineated their potential in modulating gut microbiota and immunity in aquatic animals, offering insights into the dynamic interplay between functional ingredients and immune function [47]. Complementary research has delved into the effects of antioxidant and non-antioxidant vitamin supplementation on immune function, emphasizing their impact on both innate and adaptive immune responses [48]. Additionally, investigations into the potential of food ingredients, including pro- and prebiotics, β -glucans, and fungal immunomodulatory proteins, have underscored their capacity for immune stimulation and allergic disease mitigation [49].

In the realm of animal nutrition, inquiries have probed the effects of diverse oil sources on immune function, shedding light on their influence on cytokine production and immune competence in broiler chicks [50]. Functional ingredients assume a pivotal role in averting and alleviating specific diseases prevalent among breeding animals. These ingredients, sourced from diverse origins, have been scrutinized for their potential in enhancing immune function, fostering overall health, and mitigating the incidence or severity of diseases in animals. Numerous investigations have explored the impact of functional ingredients on disease prevention and mitigation, illuminating their potential contributions to animal health and welfare.

For instance, research endeavors have elucidated the molecular mechanisms and health roles of functional ingredients, such as anthocyanins and polyphenols found in blueberries, in preventing chronic diseases in humans, thereby hinting at their potential application in animal nutrition [51]. Additionally, the review of functional components and medicinal properties of food has underscored their potential in reducing the risk of chronic degenerative diseases and promoting overall well-being [52].

Furthermore, investigations into the therapeutic potential of functional ingredients, including organopolysulfides and quercetin sourced from barley grass, have been conducted to prevent chronic diseases in humans, with implications for their application in animal health and disease prevention [53]. Additionally, examinations into the role of functional ingredients in mitigating micronutrient deficiency have provided insights into their potential application in animal nutrition to address nutritional inadequacies [54].

Moreover, discussions revolving around the management of parasites, prions, and pathogens in the global feed industry have underscored the importance of implementing biosafety and biosecurity measures to curb the spread of animal diseases through feed ingredients [55]. Additionally, explorations into the potential utilization of fruit processing by-products in the aquafeed industry have emerged as a viable strategy for enhancing intestinal microbial balance, digestibility, and local intestinal immunity in aquaculture settings [56].

5. FACTORS INFLUENCING THE EFFICACY OF FUNCTIONAL INGREDIENTS

Numerous factors contribute to the effectiveness of functional ingredients in bolstering immune function and disease resistance, encompassing aspects such as dosage, formulation, and duration of supplementation. These parameters wield substantial influence over the impact of functional ingredients on animal health and well-being. A plethora of investigations have delved into these factors, furnishing invaluable insights into their potential ramifications on immune function and disease resistance. For instance, Jagim et al. (2019) scrutinized various determinants, including physiological rationale, clinical evidence, cost-efficiency, raw material availability, patent status, and sensory attributes, shaping the development of multi-ingredient pre-workout supplements (MIPS), elucidating their potential efficacy [57]. Additionally, Haroyan et al. (2018) delved into the impact of treatment strength, baseline disease severity, delivery route, and sample size on the efficacy of curcumin, either alone or in combination with boswellic acid, in mitigating osteoarthritis [58].

Moreover, investigations into fucoxanthin have addressed aspects such as bioavailability, metabolism, safety profile, and strategies for enhancing bioavailability, shedding light on factors underpinning its efficacy [40]. Similarly, Gencoglu et al. (2020) explored the influence of dosage and supplementation duration on the efficacy of undenaturated type II collagen (UC-II) in preserving joint health, offering insights into its optimal usage [59].

Furthermore, the efficacy of prebiotics as functional food ingredients in averting diet-related diseases has been scrutinized in the context of formulation and supplementation duration, delineating factors that sway their effectiveness [60]. Likewise, Sirri et al. (2018) investigated the impact of dosage and supplementation duration on the effectiveness of curcumin, alone or in combination with vitamin E, selenium, or plant extracts, in enhancing pig health [61].

Additionally, the intricate interactions between functional ingredients and other dietary or environmental components significantly influence their effectiveness in augmenting animal health and performance.

Factors like diet composition, genetic background, and environmental conditions exert notable influence over the efficacy of functional ingredients. For instance, Glencross et al. (2007) underscored the pivotal role of ingredient digestibility, palatability, and nutrient utilization in evaluating aquaculture feeds, accentuating the intricate interplay between feed components and their impact on fish health and performance [62]. Similarly, Xue et al. (2014) delved into the additivity of apparent and standardized ileal digestibility of amino acids in diets containing multiple protein sources fed to growing pigs, elucidating potential interactions between dietary proteins and their effects on nutrient utilization [63]. These investigations yield critical insights into the potential interactions between functional ingredients and other dietary or environmental constituents, offering a holistic understanding of factors influencing animal health and performance.

6. CHALLENGES AND FUTURE DIRECTIONS

Enhancing immune health and disease resistance in breeding animals through the utilization of functional ingredients encounters various challenges and constraints. These encompass the imperative to refine formulations, identify novel ingredients, and unravel the underlying mechanisms of action. Herein lie potential avenues for future exploration:

1. **Optimization of Formulations:** The refinement of formulations is imperative to ensure the stability, bioavailability, and effectiveness of functional ingredients within animal diets. This necessitates the exploration of innovative delivery systems, encapsulation methodologies, and synergistic amalgamations of ingredients to potentiate their bioactive attributes and functional prowess [64].
2. **Discovery of Novel Ingredients:** There exists a pressing need to unearth and assess novel functional ingredients harboring inherent immunomodulatory and disease-resistant qualities. Such endeavors may entail the screening of diverse natural reservoirs, encompassing plant extracts, marine-derived compounds, and bioactive peptides, to unveil hitherto undiscovered bioactive agents with favorable impacts on animal health [65].
3. **Elucidation of Mechanisms of Action:** Future investigations should pivot towards elucidating the intricate mechanisms of action underlying the immunomodulatory and disease-resistant attributes of functional ingredients. This may entail delving into molecular and cellular realms to unravel the signaling cascades, gene expression dynamics, and metabolic responses

entwined with the immunomodulatory effects of specific ingredients [53].

4. **Gut Microbiota Interaction:** Delving into the interplay between functional ingredients and the gut microbiota assumes paramount importance in comprehending their influence on immune health. Explorations in this sphere hold promise in elucidating the prebiotic and probiotic properties of functional ingredients, along with their role in sculpting the gut microbiome to bolster immune function [65].
5. **Environmental Implications:** The assessment of the environmental footprint engendered by functional ingredients and their integration into animal production constitutes a pivotal frontier for forthcoming research. This entails a comprehensive evaluation of sustainability metrics, ecological ramifications, and ethical considerations entailed in the production and deployment of functional ingredients in animal feed formulations [66].
6. **Integration of Traditional Medicine:** Exploring the untapped potential of traditional medicine and herbal remedies as reservoirs of functional ingredients for animal health heralds as a burgeoning realm of interest. Endeavors in this domain proffer insights into the utilization of traditional medicinal flora and their bioactive constituents in fortifying immune function among breeding animals [67, 68, 69, 70].

7. CONCLUSIONS

In conclusion, the utilization of functional ingredients holds immense promise for enhancing immune health and disease resistance in breeding animals. However, this endeavor is not without its challenges and complexities. Through this review, we have elucidated various factors influencing the efficacy of functional ingredients, ranging from formulation optimization to the exploration of novel ingredients and understanding their mechanisms of action. Moreover, we have underscored the importance of investigating the interaction between functional ingredients and gut microbiota, assessing environmental impacts, and tapping into the potential of traditional medicine. As we navigate these frontiers, it becomes evident that a multidisciplinary approach, encompassing molecular biology, nutrition science, and environmental studies, is imperative to unlock the full potential of functional ingredients in promoting animal health and welfare. By addressing these challenges and advancing our understanding of functional ingredients, we pave the way for the development of innovative strategies to bolster immune function and disease resistance in breeding animals, thereby contributing to the sustainability and resilience of animal agriculture.

8. REFERENCES

- [1] Bishop, S. and Woolliams, J. (2014). Genomics and disease resistance studies in livestock. *Livestock Science*, 166, 190-198.
- [2] Vordermeier, M., Ameni, G., Berg, S., Bishop, R., Robertson, B., Aseffa, A., Young, D. (2012). The influence of cattle breed on susceptibility to bovine tuberculosis in ethiopia. *Comparative Immunology Microbiology and Infectious Diseases*, 35(3), 227-232.
- [3] Egito, A., Paiva, S., Albuquerque, M., Mariante, A., Almeida, L., Castro, S., Grattapaglia, D. (2007). Microsatellite based genetic diversity and relationships among ten creole and commercial cattle breeds raised in brazil. *BMC Genetics*, 8(1). <https://doi.org/10.1186/1471-2156-8-83>
- [4] Seabury, C., Seabury, P., Decker, J., Schnabel, R., Taylor, J., Womack, J. (2009). Diversity and evolution of 11 innate immune genes in *bos taurus taurus* and *bos taurus indicus* cattle. *Proceedings of the National Academy of Sciences*, 107(1), 151-156. <https://doi.org/10.1073/pnas.0913006107>
- [5] Ødegård, J., Baranski, M., Gjerde, B., Gjedrem, T. (2011). Methodology for genetic evaluation of disease resistance in aquaculture species: challenges and future prospects. *Aquaculture Research*, 42, 103-114. <https://doi.org/10.1111/j.1365-2109.2010.02669.x>
- [6] Martínez, A., Gama, L., Cañón, J., Ginja, C., Delgado, J., Dunner, S., Zaragoza, P. (2012). Genetic footprints of iberian cattle in america 500 years after the arrival of columbus. *Plos One*, 7(11), e49066. <https://doi.org/10.1371/journal.pone.0049066>
- [7] Freitas, T., Dias, J., Verissimo, A., Lobo, J., Costa, G., Moura, M., Fioravanti, M. (2022). Population structure of curraleiro pé-duro cattle and its relationship with the serological profile against pathogens of economic and zoonotic interest. *Frontiers in Genetics*, 13. <https://doi.org/10.3389/fgene.2022.872660>
- [8] Kadarmideen, H., Ali, A., Thomson, P., Müller, B., Zinsstag, J. (2011). Polymorphisms of the *slc11a1* gene and resistance to bovine tuberculosis in african zebu cattle. *Animal Genetics*, 42(6), 656-658. <https://doi.org/10.1111/j.1365-2052.2011.02203.x>
- [9] Öner, Y., Ata, N., Karabaş, M., Yilmaz, O. (2022). Investigation of *tlr2* -ecorv, *nod2* -bsah and *ifny* -hphi allele frequency distribution among turkish native cattle breeds. *Turkish Journal of Agriculture - Food Science and Technology*, 10(6), 992-996. <https://doi.org/10.24925/turjaf.v10i6.992-996.4701>
- [10] Bilgen, N., Kul, B., Offord, V., Werling, D., Ertugrul, O. (2016). Determination of genetic variations of toll-like receptor (*tlr*) 2, 4, and 6 with next-generation sequencing in native cattle breeds of anatolia and holstein friesian. *Diversity*, 8(4), 23. <https://doi.org/10.3390/d8040023>
- [11] Verrier, E., Dorson, M., Mauger, S., Torhy, C., Ciobotaru, C., Hervet, C., Quillet, E. (2013). Resistance to a rhabdovirus (vhsv) in rainbow trout: identification of a major qtl related to innate mechanisms. *Plos One*, 8(2), e55302. <https://doi.org/10.1371/journal.pone.0055302>
- [12] Liu, Z., Wu, T., Xiang, G., Wang, H., Wang, B., Zheng, F., Li, K. (2022). Enhancing animal disease resistance, production efficiency, and welfare through precise genome editing. *International Journal of Molecular Sciences*, 23(13), 7331. <https://doi.org/10.3390/ijms23137331>
- [13] Vitale, M., Migliore, S., Giglia, M., Alberti, P., Presti, V., Langeveld, J. (2016). Scrapie incidence and prnp polymorphisms: rare small ruminant breeds of sicily with tse protecting genetic reservoirs. *BMC Veterinary Research*, 12(1). <https://doi.org/10.1186/s12917-016-0766-9>
- [14] Dobson, B., Liggett, S., O'Brien, R., Griffin, J. (2013). Innate immune markers that distinguish red deer (*cervus elaphus*) selected for resistant or susceptible genotypes for johnes disease. *Veterinary Research*, 44(1), 5. <https://doi.org/10.1186/1297-9716-44-5>
- [15] Lyons, L., Grahn, R., Genova, F., Beccaglia, M., Hopwood, J., Longeri, M. (2016). Mucopolysaccharidosis vi in cats – clarification regarding genetic testing. *BMC Veterinary Research*, 12(1). <https://doi.org/10.1186/s12917-016-0764-y>
- [16] Egger-Danner, C., Cole, J., Pryce, J., Gengler, N., Heringstad, B., Bradley, A., Stock, K. (2015). Invited review: overview of new traits and phenotyping strategies in dairy cattle with a focus on functional traits. *Animal*, 9(2), 191-207. <https://doi.org/10.1017/s1751731114002614>
- [17] Rauw, W. (2012). Immune response from a resource allocation perspective. *Frontiers in Genetics*, 3. <https://doi.org/10.3389/fgene.2012.00267>
- [18] König, S. and May, K. (2019). Invited review: phenotyping strategies and quantitative-genetic background of resistance, tolerance and resilience associated traits in dairy cattle. *Animal*, 13(5), 897-908. <https://doi.org/10.1017/s1751731118003208>
- [19] Stonos, N., Wootton, S., Karrow, N. (2014). Immunogenetics of small ruminant lentiviral infections. *Viruses*, 6(8), 3311-3333. <https://doi.org/10.3390/v6083311>
- [20] McManus, C., Paim, T., Melo, C., Brasil, B., Paiva, S. (2014). Selection methods for resistance to and tolerance of helminths in livestock. *Parasite*, 21, 56. <https://doi.org/10.1051/parasite/2014055>
- [21] Keane, O., Dodds, K., Crawford, A., McEwan, J. (2007). Transcriptional profiling of ovis aries identifies ovdq1 allele frequency differences between nematode-resistant and susceptible selection lines. *Physiological Genomics*, 30(3), 253-261. <https://doi.org/10.1152/physiolgenomics.00273.2006>
- [22] Šwiderská, Z., Šmídová, A., Buchtová, L., Bryjová, A., Fabiánová, A., Munclinger, P., Vinkler, M. (2018). Avian toll-like receptor allelic diversity far exceeds human polymorphism: an insight from domestic chicken breeds. *Scientific Reports*, 8(1). <https://doi.org/10.1038/s41598-018-36226-1>
- [23] Goosen, N., Wet, L., Görgens, J. (2014). Comparison of hydrolysed proteins from different raw materials in diets for mozambique tilapia *oreochromis mossambicus*. *Aquaculture International*, 23(5), 1165-1178. <https://doi.org/10.1007/s10499-014-9873-4>
- [24] Singh, A., Singh, R., Tripathi, M. (2020). Photoperiodic manipulation modulates the innate and cell mediated immune functions in the fresh water snake, *natrix piscator*. *Scientific Reports*, 10(1). <https://doi.org/10.1038/s41598-020-71777-2>
- [25] Sheldon, I., Cronin, J., Bromfield, J. (2019). Tolerance and innate immunity shape the development of postpartum uterine disease and the impact of endometritis in dairy cattle.

- Annual Review of Animal Biosciences, 7(1), 361-384. <https://doi.org/10.1146/annurev-animal-020518-115227>
- [26] Hofmann, T., Schmucker, S., Bessei, W., Grashorn, M., Stefanski, V. (2020). Impact of housing environment on the immune system in chickens: a review. *Animals*, 10(7), 1138. <https://doi.org/10.3390/ani10071138>
- [27] Campbell, J., Crenshaw, J., Gonzalez-Esquerria, R., Polo, J. (2019). Impact of spray-dried plasma on intestinal health and broiler performance. *Microorganisms*, 7(8), 219. <https://doi.org/10.3390/microorganisms7080219>
- [28] Maki, J., Klima, C., Sylte, M., Looft, T. (2019). The microbial pecking order: utilization of intestinal microbiota for poultry health. *Microorganisms*, 7(10), 376. <https://doi.org/10.3390/microorganisms7100376>
- [29] Chen, J., Guo, K., Song, X., Lv-tao, L., Liu, S., Hu, R., Luo, J. (2020). The anti-heat stress effects of chinese herbal medicine prescriptions and rumen-protected γ -aminobutyric acid on growth performance, apparent nutrient digestibility, and health status in beef cattle. *Animal Science Journal*, 91(1). <https://doi.org/10.1111/asj.13361>
- [30] Polsky, L. and Keyserlingk, M. (2017). Invited review: effects of heat stress on dairy cattle welfare. *Journal of Dairy Science*, 100(11), 8645-8657. <https://doi.org/10.3168/jds.2017-12651>
- [31] Tao, S. and Dahl, G. (2013). Invited review: heat stress effects during late gestation on dry cows and their calves. *Journal of Dairy Science*, 96(7), 4079-4093. <https://doi.org/10.3168/jds.2012-6278>
- [32] Nelson, R. and Demas, G. (1996). Seasonal changes in immune function. *The Quarterly Review of Biology*, 71(4), 511-548. <https://doi.org/10.1086/419555>
- [33] McFadden, J., Girard, C., Tao, S., Zhou, Z., Bernard, J., Duplessis, M., White, H. (2020). Symposium review: one-carbon metabolism and methyl donor nutrition in the dairy cow. *Journal of Dairy Science*, 103(6), 5668-5683. <https://doi.org/10.3168/jds.2019-17319>
- [34] Khan, M., Liu, S., Ma, Y., Ma, M., Ullah, Q., Khan, I., Cao, Z. (2023). Overview of the effect of rumen-protected limiting amino acids (methionine and lysine) and choline on the immunity, antioxidative, and inflammatory status of periparturient ruminants. *Frontiers in Immunology*, 13. <https://doi.org/10.3389/fimmu.2022.1042895>
- [35] Korish, M. and Attia, Y. (2020). Evaluation of heavy metal content in feed, litter, meat, meat products, liver, and table eggs of chickens. *Animals*, 10(4), 727. <https://doi.org/10.3390/ani10040727>
- [36] Rhind, S. (2012). Anthropogenic pollutants – an insidious threat to animal health and productivity?. *Acta Veterinaria Scandinavica*, 54(S1). <https://doi.org/10.1186/1751-0147-54-s1-s2>
- [37] Bleakley, S. and Hayes, M. (2017). Algal proteins: extraction, application, and challenges concerning production. *Foods*, 6(5), 33. <https://doi.org/10.3390/foods6050033>
- [38] Rakita, S., Banjac, V., Đuragic, O., Cheli, F., Pinotti, L. (2021). Soybean molasses in animal nutrition. *Animals*, 11(2), 514. <https://doi.org/10.3390/ani11020514>
- [39] Schumann, M., Holm, J., Brinker, A. (2022). Effects of feeding an all-plant diet on rainbow trout performance and solid waste characteristics. *Aquaculture Nutrition*, 2022, 1-11. <https://doi.org/10.1155/2022/1694245>
- [40] Zhang, H., Tang, Y., Ying, Z., Zhang, S., Qu, J., Wang, X., Liu, Z. (2015). Fucoxanthin: a promising medicinal and nutritional ingredient. *Evidence-Based Complementary and Alternative Medicine*, 2015, 1-10. <https://doi.org/10.1155/2015/723515>
- [41] Fructuoso, I., Romão, B., Han, H., Raposo, A., Ariza-Montes, A., Araya-Castillo, L., Zandonadi, R. (2021). An overview on nutritional aspects of plant-based beverages used as substitutes for cow's milk. *Nutrients*, 13(8), 2650. <https://doi.org/10.3390/nu13082650>
- [42] Paramita, V., Panyoyai, N., Kasapis, S. (2020). Molecular functionality of plant proteins from low- to high-solid systems with ligand and co-solute. *International Journal of Molecular Sciences*, 21(7), 2550. <https://doi.org/10.3390/ijms21072550>
- [43] Gatlin, D., Barrows, F., Brown, P., Dąbrowski, K., Gaylord, T., Hardy, R., Wurtele, E. (2007). Expanding the utilization of sustainable plant products in aquafeeds: a review. *Aquaculture Research*, 38(6), 551-579. <https://doi.org/10.1111/j.1365-2109.2007.01704.x>
- [44] Villamor, E. and Fawzi, W. (2005). Effects of vitamin a supplementation on immune responses and correlation with clinical outcomes. *Clinical Microbiology Reviews*, 18(3), 446-464. <https://doi.org/10.1128/cmr.18.3.446-464.2005>
- [45] Faber, J., Vos, P., Kegler, D., Norren, K., Argilés, J., Laviano, A., Helvoort, A. (2008). Beneficial immune modulatory effects of a specific nutritional combination in a murine model for cancer cachexia. *British Journal of Cancer*, 99(12), 2029-2036. <https://doi.org/10.1038/sj.bjc.6604785>
- [46] Kiarie, E. and Mills, A. (2019). Role of feed processing on gut health and function in pigs and poultry: conundrum of optimal particle size and hydrothermal regimens. *Frontiers in Veterinary Science*, 6. <https://doi.org/10.3389/fvets.2019.00019>
- [47] Zhou, Z., Ringø, E., Olsen, R., Song, S. (2017). Dietary effects of soybean products on gut microbiota and immunity of aquatic animals: a review. *Aquaculture Nutrition*, 24(1), 644-665. <https://doi.org/10.1111/anu.12532>
- [48] Webb, A. and Villamor, E. (2008). Update: effects of antioxidant and non-antioxidant vitamin supplementation on immune function. *Nutrition Reviews*, 65(5), 181-217. <https://doi.org/10.1111/j.1753-4887.2007.tb00298.x>
- [49] Wichers, H. (2009). Immunomodulation by food: promising concept for mitigating allergic disease?. *Analytical and Bioanalytical Chemistry*, 395(1), 37-45. <https://doi.org/10.1007/s00216-009-2838-1>
- [50] Attia, Y., Al-Harhi, M., El-Maaty, H. (2020). The effects of different oil sources on performance, digestive enzymes, carcass traits, biochemical, immunological, antioxidant, and morphometric responses of broiler chicks. *Frontiers in Veterinary Science*, 7. <https://doi.org/10.3389/fvets.2020.00181>
- [51] Ma, L., Sun, Z., Zeng, Y., Luo, M., Yang, J. (2018). Molecular mechanism and health role of functional ingredients in blueberry for chronic disease in human beings. *International Journal of Molecular Sciences*, 19(9), 2785. <https://doi.org/10.3390/ijms19092785>
- [52] Abuajah, C., Ogbonna, A., Osuji, C. (2014). Functional components and medicinal properties of food: a review. *Journal of Food Science and Technology*, 52(5), 2522-2529. <https://doi.org/10.1007/s13197-014-1396-5>

- [53] Zeng, Y., Pu, X., Du, J., Yang, X., Li, X., Mandal, M., Yang, J. (2020). Molecular mechanism of functional ingredients in barley to combat human chronic diseases. *Oxidative Medicine and Cellular Longevity*, 2020, 1-26. <https://doi.org/10.1155/2020/3836172>
- [54] Sun, X., Sarteshnizi, R., Boachie, R., Okagu, O., Abioye, R., Neves, R., Udenigwe, C. (2020). Peptide–mineral complexes: understanding their chemical interactions, bioavailability, and potential application in mitigating micronutrient deficiency. *Foods*, 9(10), 1402. <https://doi.org/10.3390/foods9101402>
- [55] Shurson, G., Urriola, P., Ligt, J. (2021). Can we effectively manage parasites, prions, and pathogens in the global feed industry to achieve one health?. *Transboundary and Emerging Diseases*, 69(1), 4-30. <https://doi.org/10.1111/tbed.14205>
- [56] Dawood, M., Habotta, O., Elsabagh, M., Azra, M., Kari, Z., Sewilam, H. (2022). Fruit processing by-products in the aquafeed industry: a feasible strategy for aquaculture sustainability. *Reviews in Aquaculture*, 14(4), 1945-1965. <https://doi.org/10.1111/raq.12680>
- [57] Jagim, A., Harty, P., Camic, C. (2019). Common ingredient profiles of multi-ingredient pre-workout supplements. *Nutrients*, 11(2), 254. <https://doi.org/10.3390/nu11020254>
- [58] Haroyan, A., Mukuchyan, V., Mkrtchyan, N., Minasyan, N., Gasparyan, S., Sargsyan, A., Hovhannisyan, A. (2018). Efficacy and safety of curcumin and its combination with boswellic acid in osteoarthritis: a comparative, randomized, double-blind, placebo-controlled study. *BMC Complementary and Alternative Medicine*, 18(1). <https://doi.org/10.1186/s12906-017-2062-z>
- [59] Gencoglu, H., Orhan, C., Sahin, E., Sahin, K. (2020). Undenatured type ii collagen (uc-ii) in joint health and disease: a review on the current knowledge of companion animals. *Animals*, 10(4), 697. <https://doi.org/10.3390/ani10040697>
- [60] Florowska, A., Krygier, K., Florowski, T., Dłużewska, E. (2016). Prebiotics as functional food ingredients preventing diet-related diseases. *Food Function*, 7(5), 2147-2155. <https://doi.org/10.1039/c5fo01459j>
- [61] Sirri, R., Vitali, M., Zambonelli, P., Giannini, G., Zappaterra, M., Fiego, D., Davoli, R. (2018). Effect of diets supplemented with linseed alone or combined with vitamin e and selenium or with plant extracts, on longissimus thoracis transcriptome in growing-finishing italian large white pigs. *Journal of Animal Science and Biotechnology*, 9(1). <https://doi.org/10.1186/s40104-018-0297-2>
- [62] Glencross, B., Booth, M., Allan, G. (2007). A feed is only as good as its ingredients ? a review of ingredient evaluation strategies for aquaculture feeds. *Aquaculture Nutrition*, 13(1), 17-34. <https://doi.org/10.1111/j.1365-2095.2007.00450.x>
- [63] Xue, P., Ragland, D., Adeola, O. (2014). Determination of additivity of apparent and standardized ileal digestibility of amino acids in diets containing multiple protein sources fed to growing pigs1. *Journal of Animal Science*, 92(9), 3937-3944. <https://doi.org/10.2527/jas.2014-7815>
- [64] Cauvain, S. (2015). Functional ingredients., 57-99. https://doi.org/10.1007/978-3-319-14687-4_3
- [65] Piao, M. Y., Tu, Y., Zhang, N., Diao, Q., Bi, Y. (2023). Advances in the application of phytogetic extracts as antioxidants and their potential mechanisms in ruminants. *Antioxidants*, 12(4), 879. <https://doi.org/10.3390/antiox12040879>
- [66] Galvan, D., Eftting, L., Cremasco, H., Conte-Junior, C. (2021). Recent applications of mixture designs in beverages, foods, and pharmaceutical health: a systematic review and meta-analysis. *Foods*, 10(8), 1941. <https://doi.org/10.3390/foods10081941>
- [67] Xu, H., Zhang, Y., Liu, Z., Chen, T., Lv, C., Tang, S., Huang, L. (2018). EtcM: an encyclopaedia of traditional chinese medicine. *Nucleic Acids Research*, 47(D1), D976-D982. <https://doi.org/10.1093/nar/gky987>
- [68] Gheorghe-Irimia, R. A., Tăpăloagă, D., Tăpăloagă, P. R., Ilie, L. I., Şonea, C., Serban, A. I. (2022). Mycotoxins and Essential Oils—From a Meat Industry Hazard to a Possible Solution: A Brief Review. *Foods*, 11(22), 3666.
- [69] Tudor, L., Pişuru, M. T., Gheorghe-Irimia, R. A., Şonea, C., & Tăpăloagă, D. (2023). Optimizing milk production, quality and safety through essential oil applications. *Farmacia*, 71(5)
- [70] Irimia, R. A., Georgescu, M., Tudoreanu, L., & Militaru, M. (2020). Testing The Effect Of Nigella Sativa Essential Oil Solution On Chicken Breast pH And Total Volatile Base Nitrogen During Refrigeration. *Scientific Works. Series C, Veterinary Medicine*, 66(2).

STUDY ON THE EVOLUTION OF GENETIC RESOURCES OF DOMESTIC ANIMALS IN ROMANIA

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Abstract

The paper proposes the identification of animal breeds at risk of abandonment and the analysis of animal genetic resources from the perspective of the evolution of total herds and genetic quality determination programs.

Data from the National Institute of Statistics show that in the period 2015-2022, Romania recorded a decline in the total livestock of cattle (-12.34%) and pigs (-32.44%) and slight increases in the total sheep and goats. On the other hand, the National Agency for Animal Husbandry indicates significant decreases in the number of breeding females, both in cattle (-14.7%) and pigs (-32.5%). Within the 4 species of animals analysed (cattle, sheep, goats and pigs), 14 breeds in danger of abandonment were identified, generally native breeds with lower production potential than that of improved breeds. For the identified animal breeds, genetic quality determination programs have been approved, which are implemented by animal breeders' associations accredited for the establishment and management of Genealogical Registries.

Maintaining the genetic diversity of local breeds in danger of abandonment can contribute to the diversification of existing populations, to restoring the vitality of selected lines, to increasing the productivity and disease resistance of animals.

Keywords: genetic resources, animal breeds, livestock, genetic quality

1. INTRODUCTION

Humanity benefits in a multitude of ways from the biodiversity in the surrounding environment. Although its value is difficult to quantify in monetary terms, biodiversity has a positive impact on the quality of life physically or as a source of education and inspiration [7]. Despite the recognition of the crucial role of biodiversity in maintaining human and planetary health, biodiversity is declining faster than at any time in human history [1]. In the last 50 years, globally, biodiversity has been severely compromised and altered, the global rate of species extinction is hundreds of times higher than the average rate of the last 10 million years. About a quarter of species in most groups of plants and animals are already threatened with extinction and about 1 million species are at risk of extinction in the coming decades [8,9].

Between 1970 and 2018, the estimated population size of mammals, birds, fish, amphibians and reptiles declined by an average of about 68% [5]. Biodiversity loss is seen in both agriculture and wildlife; many of the domesticated plant and animal species that were important food sources disappeared. Biodiversity is constantly being degraded, due to the way natural resources are exploited to support the production, consumption and trade of a globalized economy.

The human impact on animal biodiversity, leading to the extinction of some species or a decrease in the abundance of local species, is a less recognized form of global environmental change.

In a study on anthropogenic biodiversity loss, Dirzo R. et al., (2014 [2]) shows that out of 1500 species of terrestrial vertebrates studied, 322 species disappeared and the abundance of the populations of the remaining species

decreased by 25%. For the invertebrate species studied, the results show that 67% of the monitored populations showed an average decrease in abundance of 45%.

Globally, the livestock sector occupies approximately 78% of agricultural land. The conversion of land for agriculture results in habitat destruction and loss of biodiversity because deforestation of natural ecosystems (such as forests) removes sources of shelter and food on which the survival of wild species depends [3]. In the "Red List" drawn up by the International Union for Conservation of Nature (IUCN), agriculture is identified as the main threat to 24,000 of the 28,000 species documented by the IUCN as being at risk of extinction. [6].

In all livestock systems, farm animal species play an essential role in maintaining food security and meeting the socio-economic needs of a significant part of the world's population.

Worldwide, about 40 species of animals have been domesticated for use in agriculture, food production. Five of these species (cattle, sheep, pigs, goats and chickens) are dominant both in terms of herd size and their geographical distribution. According to FAO data [4], cattle, sheep and chickens are widely found in all regions of the world while goats and pigs are less evenly distributed regionally. On the other hand, FAO data on the proportion of domesticated and farmed animal breeds at risk of extinction show that for 62% of local breeds the risk status remains unknown while 70% of local breeds with a known status are in danger of extinction (Figure no. 1).

Regionally, in 2023, the proportion of endangered local breeds was up to 82% in North America and Europe (FAO, 2023 [10]).

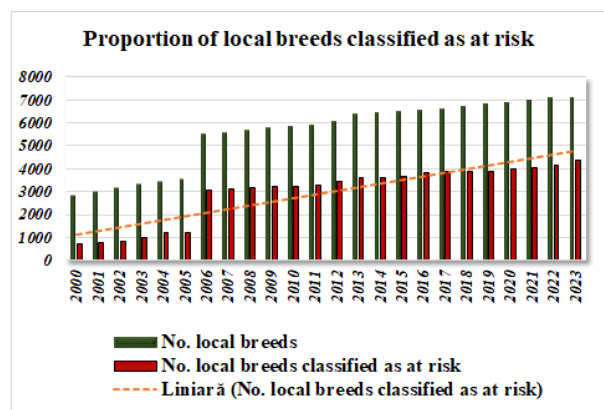


Figure no. 1: Status of local breeds globally, in the period 2000-2023

Source: FAO, [10]

In the medium and long term, maintaining the biodiversity of farm animals is achieved by two methods: *in situ* conservation (live animals are maintained and used in the livestock production system) and *ex situ* conservation (storage of cryopreserved genetic material in gene banks). Regarding *ex situ* conservation, FAO data indicate a very small number of local breeds (287 out of 7,688 local breeds) and transboundary breeds (175 out of 1,115 transboundary breeds) for which there is sufficient conserved genetic material (FAO, 2023 [10]).

2. MATERIALS AND METHODS

The article proposes an analysis of the evolution of genetic resources in the animal breeding sector. The analysis is oriented towards the identification of animal breeds at risk of abandonment and the analysis of animal genetic resources from the perspective of the evolution of total herds under production control and genetic quality determination programs

For the documentation part, a series of scientific papers with relevant results in the field of biodiversity and special reports on the conservation of genetic resources were studied.

Data from the National Institute of Statistics (NIS), the National Agency for Animal Husbandry (NAAH), the Food and Agriculture Organization of the United Nations (FAO) and the European Environment Agency (EEA) were used for the analysis of genetic resources. The data on the evolution of the studied indicators (animal numbers, animal breeds, genetic quality determination programs) were systematized, processed, presented synthetically in tables and extensively interpreted in the paper.

3. RESULTS AND DISCUSSIONS

In Romania, the phenomenon of urban expansion, manifested after 1990, greatly expanded the built-up land, which led to the fragmentation of natural and semi-natural habitats and the reduction of biodiversity. According to NIS data, only in the period 2000-2014 the area occupied by constructions increased by 19.8%, the

growth trend also manifesting itself in the following years and affecting agriculture as a whole.

Within agriculture, the livestock sector is one of the most difficult problems of today's agriculture, registering a decline in herds of the main animal species, both in the public and private sectors. If we analyse the NIS data, regarding the evolution of animal herds by species (table no. 1), we notice that, in the period 2015-2022, Romania recorded significant decreases in the total herds of cattle species (-12.34%) and pigs (-32.44%), respectively slight increases in total flocks of sheep (+4.45%) and goats (+2.98%).

Table no. 1: The evolution of total livestock numbers in Romania, in the period 2015-2022

Effective (thousand head)	2015	2020	2021	2022	Variation 2022/2015 (±%)
Cattle					
Total of which:	2092	1875	1827	1834	-12.34%
Cows, buffaloes and heifers	1311	1231	1193	1194	-8.93%
Swine	4927	3785	3620	3329	-32.44%
Breeding sows	375	316	299	285	-24.0%
Sheep	9810	10282	10087	10247	+4.45%
Breeding shep	8330	8812	8765	8879	+6.59%
Goats	1440	1612	1493	1483	+2.98%
Breeding goats	1133	1291	1218	1215	+7.23%

Source: Author's calculations based on data from the National Institute of Statistics

The decrease in the total herds of bovine and porcine species is also visible with regard to the mother herds. Thus, during the analysed period, the female herd of cattle (milk cows, breeding buffaloes and breeding heifers) decreased by 8.93%, while the female herd of pigs (sows) decreased by 24, 0% This affected the breeding sector in both species by decreasing the number of replacement heifers and sows.

On the other hand, if we analyse the data of the National Agency for Animal Husbandry (ANZ), the unit that coordinates the improvement, reproduction and conservation of animal genetic resources, we notice that in the bovine species the female herd suitable for reproduction decreased by 12.5%, in the period 2019-2023, against the background of the 14.7% decrease in the total breeding female population and the 13.5% decrease in the female population registered in production control (table no. 2).

In the *taurine species*, the decrease in total herds has affected the breeding sector. Thus, in the period 2019-2023, the total number of females under production control decreased by approximately 14%, the number of breeding females decreased by 15%, and the number of breeding female bulls by 12.4% (table no. 2).

Table no. 2: Evolution of the female herd registered in production control for the bovine species, in the period 2019-2023

Females (thousand head)	2019	2020	2021	2022	2023	2023/2019 (±%)
CATTLE						
Registered females	1451.9	1356.6	1355.0	1321.3	1255.8	-13.5%
Reproductive females	903.6	846.2	846.5	826.3	770.8	-14.7%
Females fit for reproduction	1057.1	991.6	1.004.2	984.6	926.0	-12.4%
COWS						
Registered females	1435.1	1339.4	1337.2	1302.6	1235.7	-13.9%
Reproductive females	893.0	835.5	835.3	815.1	759.0	-15.0%
Females fit for reproduction	1044.4	978.6	990.6	970.7	911.0	-12.7%
BUFFALO						
Registered females	16.8	16.3	16.7	17.8	18.7	+11.0%
Reproductive females	10.6	10.3	10.6	10.7	11.3	+6.8%
Females fit for reproduction	12.7	12.3	12.7	13.3	13.9	+9.2%

Source: Author's calculations based on data from the National Agency for Animal Husbandry

In the *buffalo species*, since 2015, due to the increase in consumer demand for milk and buffalo milk products (especially in Transylvania), the total number of buffaloes has increased. In the period 2015-2022, the evolution of the total buffalo herds was a fluctuating one, being also influenced by the state subsidy for animals registered at Payments and Intervention Agency for Agriculture (164 euros/year/head of buffalo) and the subsidy for breeds in danger of abandonment (200 euros/year/buffalo head).

According to NAAH data (table no. 2), in the period 2019-2023, in the buffalo species there were increases of 6.8% in the herd of females for reproduction, of 11% of the herd of females registered in production control and of 9, 2% of the breeding female population.

In Romania, the genetic improvement, conservation and reconstitution programs of some breeds are run by accredited/authorized associations, to which animal breeders have joined, under the coordination, control and verification of the National Agency for Animal Husbandry. NAAH is the approving authority for endangered species conservation programs and authorizes/accredits animal associations that establish and maintain farm animal herd registries for endangered local breeds.

Maintaining the genetic quality of livestock is based on genetic improvement and progeny testing of livestock. To this end, a number of programs are carried out under the authority of NAAH to determine the genetic quality of livestock and to establish and maintain herd registers. According to NAAH data for the year 2023, in the taurine species, a number of 36 associations authorized to

determine the genetic quality have run 19 genetic improvement programs for the Baltata with Black Romanian type Holstein Frize, Baltata Romanian Simmental type, Montbéliard, Brown, Aberdeen Angus, Charolais, Limousine, Aubrac, Galloway, Highland, Sura de Stepa – Hungarian Gray, Sellers and Jersey.

If we analyse the NAAH data on the evolution of bull breeding programs (table no. 3), in the period 2019-2023, we notice that starting from 2021, two new genetic breeding programs for the Salers and Jersey bull breeds have started. On the other hand, we observe a 59.6% increase in the number of bull breeders involved in genetic improvement programs (26,557 breeders in 2023 compared to 16,635 breeders in 2019) and a 22.3% increase in the number of tested animals (461,308 head in 2023 compared to 377,165 head in 2021).

Table no. 3: The evolution of genetic quality determination programs in the taurine species in the period 2019-2023

Specification	2019	2020	2021	2022	2023
IMPROVEMENT PROGRAMS					
Accredited societies for the determination of genetic quality	37	40	37	37	36
Total breeders participating in the running of the programs	16,635	26,249	17,016	15,142	26,557
Total improvement programs of which for breeds:	13	13	17	19	19
Baltata with Black Romanian type Holstein Frize	2	2	2	2	2
Baltata Romanian Simmental type	2	2	3	5	5
Montbéliard	1	1	2	2	2
Brown	1	1	1	1	1
Aberdeen Angus	1	1	1	1	1
Charolais	1	1	1	1	1
Limousine	1	1	1	1	1
Aubrac	1	1	1	1	1
Galloway	1	1	1	1	1
Highland	1	1	1	1	1
Sura de Stepa – Hungarian Gray	1	1	1	1	1
Sellers	-	-	1	1	1
Jersey	-	-	1	1	1
BREED CONSERVATION AND RECONSTITUTION PROGRAMS					
Societies accredited for the preparation and maintenance of the genealogical register	9	9	10	10	10
Sura de Stepa breed conservation program	1	1	1	1	1
Reconstitution program of the Pinzgau de Transilvania breed	1	1	1	1	1
Animals tested (heads)	377,165	372,833	416,765	360,045	461,308

Source: National Agency for Animal Husbandry

For the *buffalo species*, NAAH approved a genetic improvement program for the Romanian Buffalo breed, a program implemented by the Association of Transylvanian Buffalo Breeders. NAAH data indicates for the year 2021, a herd of 5,968 tested animals and a number of 1,683 breeders participating in the program. The year 2022 saw an 82.9% increase in the herd of tested animals (10,917 heads in 2022 compared to 5,968 in 2021) and a 33.7% increase in the number of breeders

enrolled in the program (2,250 in 2022 compared to 1,683 in 2021).

In *sheep*, over the period 2019-2022, NAAH data shows an 8.7% decrease in the ewes registered in production control and a 9.5% decrease in the total ewes for breeding. In the case of *goats*, NAAH data, regarding the evolution of the total herd of goats under production control, show that while the total female herd registered in production control decreased by 24%, there was a 23.6% decrease in the female herd for reproduction and a 37.7% reduction in the breeding female population (table no. 4).

Table no. 4: The evolution of the female herd registered in the production control for sheep and goat species, in the period 2019-2023

Females (thousand head)	2019	2020	2021	2022	2023	2023/2019 (±%)
SHEEP						
Registered females	10080.0	9818.0	9584.5	9371.8	9200.3	-8.7%
Reproductive females	7492.4	7366.0	7228.4	6991.9	6784.0	-9.5%
Females fit for reproduction	8008.9	7816.7	7635.3	7384.7	7221.2	-9.8%
GOATS						
Registered females	1628.0	1544.6	1392.2	1339.2	1237.3	-24.0%
Reproductive females	1166.9	1105.8	1000.2	977.0	891.2	-23.6%
Females fit for reproduction	1269.3	1207.7	1088.6	1051.7	970.8	-37.7%

Source: National Agency for Animal Husbandry

In *sheep*, NAAH data shows an increase in the number of accredited associations for the preparation and maintenance of pedigree registers by breed, from 56 accredited associations (with 6,416 breeders) in 2019 to 62 accredited associations (with 10,077 breeders) in 2022. The 62 associations, authorized by NAAH to determine the genetic quality of the sheep stock, have run 20 breeding/conservation programs on a total stock of 2,977,189 sheep.

In the *goat* species, in 2022, 11 breeders' associations accredited to determine the genetic quality ran 6 improvement/conservation programs for a herd of 230,595 goats.

In the *pig* species, African swine fever has decimated pig herds and reduced the number of breeders. If we analyse the NAAH data, regarding the evolution of the herd of females for reproduction in the pig species, in the period 2019-2023, we observe a decrease in the female herd registered in production control by 37.6% (- 96,081 heads in the analysed period) and the total herd of females for reproduction by 35.2% (table no. 5).

NAAH data shows that, in 2022, genetic improvement programs in the pig species were carried out by 4 associations accredited for the preparation and maintenance of the genealogical register (in which 24 breeders participated) on a herd of 14,842 purebred pigs. Another 8 holdings carried out breeding programs with

hybrid breeding pigs on a herd of 22,019 heads and one association carried out two conservation programs for native breeds, on a herd of 1,853 heads (21.35% lower than the one in 2021).

Table no. 5: The evolution of the female herd registered in the production control for the swine species, in the period 2019-2023

Females (thousand head)	2019	2020	2021	2022	2023	2023/2019 (%)
SWINE						
Registered females	255.3	234.1	219.4	168.7	159.2	-37.6
Reproductive females	178.8	181.5	163.8	126.0	115.9	-35.2
Females fit for reproduction	217.1	207.8	191.6	147.4	137.5	36.6

Source: National Agency for Animal Husbandry

With regard to native breeds of animals, 21 breeds of animals have been identified at the national level in different degrees of risk, namely: taurine species - Sura de Stepa; la bubaline – Romanian buffalo; sheep - Ratca, Merinos de Palas, Merinos de Cluj, Merinos de Transilvania, Merinos de Suseni, Oaia cap negru de Teleorman, Karakul de Botoşani, Tigaie Ruginie; for goats: Alba de Banat and Carpatina; for pigs: Bazna and Mangaliţa; for horses: Furioso North Star, Hutul, Gidran, Lipitan and Shagya Araba.

For some of these breeds, conservation programs are underway that aim to save the breeds, maintain a valuable genetic background and continuously increase the herd of purebred animals in order to avoid the danger of inbreeding.

In 2022, nationally, there were 11 associations accredited by NAAH to maintain genealogical registers for 16 animal breeds of bulls, buffaloes, sheep, goats and pigs. In the equine species, the genealogical registers for the 5 breeds identified as being at risk of abandonment are maintained by NAAH.

In 2019, NAAH approved the conservation program for the local Sura de Stepa bull breed, a breed at critical risk of extinction. The Sura de Stepa breed has played a particularly important biological role in the creation of improved taurine breeds in our country and constitutes a valuable biological material due to its adaptability, resistance and combinative capacity in crossing with other breeds. At the date of approval of the conservation program, the total herd of cows of known origin was 30 heads at the Cattle Breeding Research and Development Station - Dancu Iasi.

For the sheep species, conservation programs are ongoing for sheep breeds that are in danger of being abandoned, respectively: Ratca, Merinos de Palas, Merinos de Cluj, Merinos de Transilvania, Merinos de Suseni, Oaia Cap Negru de Teleorman, Karakul de Botosani and Tigaie Ruginie.

Regarding the conservation programs of the local breeds on the way to abandonment, the Alba de Banat and

Carpatina breeds were identified whose conservation programs are run by the National Association of Goat Breeders from Romania "Caprirom", an association authorized by NAAH for the establishment and keeping genealogical records for this species.

The emergence of support programs for pig breeders from the Bazna and Mangalita breeds has recently led to an increase in the total number of pigs from the two breeds, an estimate of the total livestock for the year 2021, being approximately 20,000 Mangalita pigs and 600 heads of Bazna pigs, mostly animals of no known ancestry. These livestock are arranged in 250-280 holdings with a number of 50-400 heads/farm. In the year 2022, the total herd of pigs from the Mangalita and Bazna Breeds was 1,853 pig heads in the conservation programs carried out by the Mangalita and Bazna Domestic Pig Breeders Association.

4. CONCLUSIONS

Local breeds of animals have a low production potential, which causes breeders' interest in a particular breed to decrease to the point of reducing the herd or even its disappearance.

In Romania, the decisions taken at the level of agriculture correlated with the economic pressure, led to the continuous reduction of the number of animal breeds used for production. This has had a negative influence on genetic diversity, the possibility of improving existing traits within breeds and developing new characteristics in response to consumer needs.

The decline of local breeds began in the 1970s, when many of the local breeds were no longer used in intensive breeding due to low yields. Thus, the import of animals from breeds with higher production performance than the existing ones was encouraged, a fact that led to the disappearance of some local breeds. Most of the time, the effects of policies and legislation governing the livestock sector are not favorable to the use of local breeds of animals.

The productivity, adaptability and resilience of agricultural ecosystems depend, among other things, on the availability of a rich genetic heritage of animal breeds.

Maintaining the genetic diversity of local breeds at risk of abandonment can contribute to diversifying existing populations, restoring the vitality of selected lines, increasing productivity and disease resistance of animals.

5. REFERENCES

- [1] Ceballos, G., Ehrlich, P. R. and Raven, P. H. (2020), 'Vertebrates on the brink as indicators of biological annihilation and the sixth mass extinction', *Proceedings of the National Academy of Sciences*, 117(24): 13596–13602, doi: 10.1073/pnas.1922686117
- [2] Dirzo R, Young HS, Galetti M, Ceballos G, Isaac NJB, Collen B. (2014), *Defaunation in the Anthropocene*. *Science*; 345: 401–406. <https://doi.org/10.1126/science.1251817> PMID: 25061202
- [3] Donald P.F., Green R.E., Heath M.F., (2001), *Agricultural intensification and the collapse of Europe's farmland bird populations*, *Proc R soc Lond B Biol Sci* 2001, 268: 25-29
- [4] FAO, (2023), *Tracking progress on food and agriculture-related SDG indicators 2023*. Rome. <https://doi.org/10.4060/cc7088en>
- [5] IPBES (2019), *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, ISBN No: 978-3-947851-13-3, https://ipbes.net/sites/default/files/2020-02/ipbes_global_assessment_report_summary_for_policymakers_en.pdf
- [6] Ritchie, H. and Roser, M. (2019), 'Environmental impacts of food and agriculture', *Our World in Data*, September 2019, <https://ourworldindata.org/environmental-impacts-of-food#environmental-impacts-of-foodand-agriculture>
- [7] White, M. P., Alcock, I., Grellier, J., Wheeler, B. W., Hartig, T., Warber, S. L., Bone, A., Depledge, M. H. and Fleming, L. E. (2019), 'Spending at least 120 minutes a week in nature is associated with good health and wellbeing', *Scientific Reports*, 9(7730), doi: 10.1038/s41598-019-44097-3
- [8] WWF (2020), *Living Planet Report 2020 - Bending the curve of biodiversity loss*. Almond, R.E.A., Grooten M. and Petersen, T. (Eds). WWF, Gland, Switzerland, https://wwfin.awsassets.panda.org/downloads/lpr_2020_full_report.pdf
- [9] WWF (2022) *Living Planet Report 2022 – Building a nature-positive society*. Almond, R.E.A., Grooten, M., Juffe Bignoli, D. & Petersen, T. (Eds). WWF, Gland, Switzerland, [lpr_2022_full_report_1.pdf](https://wwfin.awsassets.panda.org/downloads/lpr_2022_full_report_1.pdf) (panda.org)
- [10] ***FAO (2023), <https://www.fao.org/sustainable-development-goals-data-portal/data/indicators/proportion-of-local-breeds-classified-as-being-at-risk-of-extinction/en>

OPTIMIZING FEED FORMULATION STRATEGIES FOR ATTAINING OPTIMAL NUTRITIONAL BALANCE IN HIGH-PERFORMING DAIRY GOATS IN INTENSIVE FARMING PRODUCTION SYSTEMS

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Abstract

Genetic factors play a pivotal role in shaping feed formulation strategies for dairy goats, influencing milk production, composition, and overall productivity through the modulation of genetic parameters and polymorphisms associated with milk protein fractions and yield. Moreover, environmental challenges, including heat stress and feed availability fluctuations, pose significant hurdles in achieving optimal nutrition and performance, necessitating precision livestock farming and the utilization of local by-products to mitigate their impact on herd health and productivity. In addition, nutritional interventions, such as supplement utilization and alternative feed incorporation, offer promising avenues for addressing specific deficiencies and enhancing overall performance, from fatty acid supplementation to herbal feed additives, while balancing rations to meet evolving nutritional needs and ensuring long-term sustainability remains paramount for optimizing herd nutrition, health, and performance in intensive dairy goat production systems. The aim of this study was to explore the multifaceted influences of genetic factors, environmental challenges, and nutritional interventions on feed formulation strategies and overall herd nutrition, health, and performance in intensive dairy goat production systems.

Keywords: dairy goats, feed formulation, genetic factors, environmental challenges, nutritional interventions

1. INTRODUCTION

Maximizing feed efficiency in dairy goat husbandry plays a pivotal role in augmenting milk productivity and safeguarding the overall well-being of the livestock. The economic significance of dairy goat farming resonates across diverse locales, including the Mediterranean basin, China, and sub-Saharan Africa, where a burgeoning appetite for dairy goat commodities persists [1,2,3]. Pertinent challenges, such as operational efficacy, waste management intricacies, and animal welfare prerogatives, are discernible within the dairy goat sector, notably prevalent in the Americas [3]. Additionally, the burgeoning demand for goat-derived dairy products catalyzes the proliferation of commercial dairy goat enterprises in the United States [3].

The availability and caliber of feed reservoirs exert profound ramifications on dairy goat agribusiness. Within regions constrained by land scarcity, the judicious exploitation of diversified feedstock, encompassing crop residues, agro-industrial byproducts, and alimentary discards, becomes indispensable in surmounting productivity thresholds [4]. Moreover, the inadequacy of grazing pastures, particularly during arid spells, prompts the incorporation of imported conventional feed constituents into dairy goat rations [5]. The dietary regimen for dairy ovine and caprines in Greece, for instance, predicates on a synergistic amalgam of seasonal

herbage foraging and supplementary nourishment, accentuating the exigency of an equilibrated and sustainable alimentation stratagem [6].

Beyond dietary composition, the deployment of feed additives and supplements constitutes a focal point of scholarly inquiry. Investigative endeavors have scrutinized the efficacy of feed supplements vis-à-vis dairy goat cohorts, with a view to ameliorating feed protein utilization efficiency and overarching lactogenic proficiency [7,8]. Furthermore, the ramifications of chronic thermal stress on lactational aptitude in dairy goats have undergone scientific scrutiny, underscoring the pivotal role of environmental variables in feed optimization and lacteal output [9].

The optimization of feed dynamics in dairy goat production transcends mere yield augmentation, encapsulating a broader paradigm of animal welfare enhancement. Pioneering feed management methodologies, such as the assimilation of feed additives, hold promise in fortifying environmental integrity and elevating the nutritional quotient of dairy goat derivatives [10]. Moreover, delving into the nexus between feed regimes and the transcriptomic milieu of lactating dairy goat leukocytes furnishes invaluable insights into the physiological responses of livestock to divergent nutritional stimuli [11].

The aim of this review paper is to comprehensively assess the current state of knowledge regarding feed formulation strategies in dairy goat production systems, with a focus

on optimizing nutritional balance to enhance milk production and ensure the overall health and welfare of the animals. Additionally, the paper aims to explore the economic, environmental, and physiological factors influencing feed optimization practices, while also examining emerging trends and innovative approaches in the field.

2. NUTRITIONAL REQUIREMENTS OF HIGH-PERFORMING DAIRY GOATS

The energy requisites of high-performing dairy goats are subject to multifaceted influences, encompassing factors such as heat stress, dietary supplementation modalities, and metabolic intricacies. Scientific investigations have delineated how heat stress perturbations can engender alterations in the thermophysiological parameters and lactational performances of dairy goats, thereby exerting discernible ramifications on their energy equilibrium and overarching metabolic milieu [11,12]. Additionally, inquiries into the effects of propylene glycol supplementation amidst heat-stressed dairy goats have elucidated its impact on milk productivity and energetic metabolism across divergent environmental milieus, underscoring its potential significance [13]. Furthermore, the evaluation of multinutrient blocks, integrating constituents like avocado pulp and peels, has shed light on alternative nutritional paradigms aimed at bolstering energy requisites, thereby enriching our understanding of dietary strategies in dairy goat management [14].

Moreover, scientific endeavors have scrutinized the efficacy of dietary supplements, such as zinc-methionine, in ameliorating milk production outcomes and udder health in dairy goats, accentuating the pivotal role of specific nutrients in fulfilling the energy demands of high-performing dairy goats [15]. Additionally, investigations into the ameliorative effects of berberine supplementation on energy balance, glucose homeostasis, and hepatic functionality in transition dairy goats have underscored the potential for targeted nutritional interventions in fortifying energy metabolism dynamics within dairy goat cohorts [16].

The protein exigencies of high-performing dairy goats are similarly subject to diverse influences, including heat stress dynamics, dietary supplementation paradigms, and metabolic responses. Scientific inquiry has elucidated how heat stress perturbations can instigate modifications in the thermophysiological parameters and lactational performances of dairy goats, thereby impinging upon their energy equilibrium and overarching metabolic milieu [12]. Furthermore, investigations into the efficacy of propylene glycol supplementation amidst heat-stressed dairy goats have shed light on its consequential impact on milk productivity and energetic metabolism across varying environmental contexts, thus delineating its potential relevance [13].

Moreover, the exploration of dietary interventions, such as multinutrient blocks, has yielded insights into alternative nutritional strategies aimed at supporting protein requirements, thereby enriching our understanding of dietary modulation in dairy goat husbandry.

Furthermore, scientific inquiries have delved into the interplay between water requisites and various factors such as heat stress dynamics, dietary constitution, and lactational performance among high-performing dairy goats. Investigations have evidenced that heat stress exerts a pronounced influence on water intake patterns among dairy goats, with lactating does experiencing a notable surge in water consumption under such thermal exigencies [12]. Additionally, inquiries into dietary cation and anion differences (DCAD) have elucidated their impact on water balance dynamics, wherein goats from the DCAD group exhibited augmented apparent water balance over a 24-hour period [17]. Moreover, studies on dietary roughage composition have revealed discernible effects on water intake behaviors, with the inclusion of spineless cactus notably diminishing water consumption via traditional drinkers [18]. Additionally, investigations into water preference modalities, such as water nipples versus water bowls, have yielded insights into the nuanced drinking patterns and water intake propensities among dairy goat populations [19]. Furthermore, scientific inquiries into the physiological responses and lactational performances of late-lactation dairy goats under heat stress conditions have unveiled a substantial augmentation in total water evaporation rates among heat-stressed goats vis-à-vis those reared under thermoneutral conditions [20].

3. FACTORS INFLUENCING FEED FORMULATION IN INTENSIVE DAIRY GOAT PRODUCTION

Genetic determinants wield substantial influence over feed formulation and management strategies within intensive dairy goat production systems. The genomic architecture inherent to dairy goat breeds intricately influences myriad aspects of feed formulation, encompassing milk production, compositional attributes, and overall productivity metrics. Empirical studies have delineated the genetic underpinnings of total lactation yields encompassing milk, fat, protein, and somatic cell score in dairy goats, thereby elucidating the genetic imprints upon both qualitative and quantitative facets of milk production [21]. Moreover, investigations into the genetic variability within dairy goat cohorts have underscored its consequential impact on a spectrum of milk production, reproductive, and immunity traits, thereby spotlighting the genetic bedrock underpinning productivity and health parameters in dairy goat populations [22,23].

Furthermore, the genetic architecture delineated by polymorphic variations in key genes, such as CSN1S1 and CSN2, has been correlated with discernible variances in

milk protein fractions and milk yield, thus furnishing insights into the intricate genetic regulation governing milk composition and output dynamics within dairy goat cohorts [24,25]. Delving deeper into the genetic milieu, explorations into the genetic diversity and ancestral origins of dairy goat breeds have provided invaluable insights into the foundational genetic drivers shaping productivity and adaptability across diverse demographic clusters [26].

Beyond milk production metrics, genetic determinants extend their purview to encompass conformational traits, the investigation of which has yielded illuminating insights into their interplay with milk yield trajectories across lactation cycles, thereby elucidating the genetic modulation of structural attributes and milk productivity in dairy goat populations [27]. Moreover, the recognition of genetic enhancement avenues has emerged as a pivotal imperative in augmenting productivity and performance metrics, thereby underscoring the indispensable role of genetic selection and breeding paradigms within intensive dairy goat production ecosystems [28, 4].

Concurrently, environmental dynamics emerge as pivotal determinants in shaping feed formulation and management paradigms within intensive dairy goat production systems. The valorization of agricultural by-products, such as residual fruits from tomato and cucumber processing, has been scrutinized for its efficacy in augmenting nutrient utilization, ruminal fermentation dynamics, microbial abundances, and milk yield and composition profiles in dairy goat herds [29]. This highlights the potential of leveraging by-products to curtail feeding costs and ameliorate environmental repercussions associated with waste accumulation.

Moreover, the intensification trajectory of dairy goat farming has garnered attention due to its discernible impact on the environmental footprint of milk production. Comparative evaluations across farm clusters, characterized by varying intensification levels, have unveiled akin environmental performances on a product-centric basis, thereby illuminating the intricate interplay between intensification paradigms, management modalities, and environmental ramifications within dairy goat production domains. Furthermore, the advent of precision livestock farming holds promise in augmenting environmental sustainability benchmarks and curbing greenhouse gas emissions within intensive dairy goat production landscapes [30].

Additionally, the adoption of efficient reproductive and herd health management practices has been discerned as pivotal in sculpting milk yield trajectories, reproductive efficiency indices, and overall productivity metrics within dairy goat enterprises. Insights gleaned from structural equation modeling have further elucidated the intricate interplay between education, training interventions, and management frameworks, ultimately reverberating upon

the production performance dynamics of dairy goat enterprises.

Furthermore, the judicious utilization of agricultural by-products and the integration of pasture management methodologies have emerged as efficacious management modalities shaping feed formulation dynamics and nutrient utilization metrics within dairy goat production landscapes. The substitution of conventional ingredients with by-products has been underscored as a means to slash feeding costs and bolster profit margins, thereby accentuating the transformative potential of sustainable feed resources within dairy goat husbandry.

Moreover, the strategic deployment of feeding and nutrition management strategies assumes paramount significance in augmenting growth performance and productivity benchmarks within dairy goat cohorts. Investigations into the supplementation regimens incorporating mineral blocks and a cocktail of fatty acids, organic acids, and minerals have shed light on their consequential impact on milk yield trajectories and hematological profiles among dairy goat populations, thus underscoring the pivotal role of efficacious feeding management strategies in dairy goat farming.

4. FEED INGREDIENTS AND THEIR ROLE IN DAIRY GOAT NUTRITION

Forages serve as linchpins in the nutritional paradigm and overall welfare of dairy goats. The integration of forages into dairy goat diets has undergone extensive scrutiny due to its profound implications on milk production, nutrient assimilation, and animal well-being. These forages impart indispensable nutrients, such as fiber, protein, and minerals, pivotal for sustaining the health and productivity of dairy goats [31]. Their inclusion in dietary regimens exerts discernible influences on milk production, composition, and sensory attributes, underscoring their pivotal role in optimizing both the quality and quantity of milk output [32].

Moreover, the nutritional constitution inherent to forages significantly shapes the quality and constituents of goat milk. Investigations have delved into the fatty acid profiles, protein contents, and mineral compositions of goat milk vis-à-vis distinct forage species and dietary regimes, illuminating the profound repercussions of forages on the nutritional milieu of milk [33,34]. Furthermore, the incorporation of forages has been linked to nuanced shifts in ruminal microbiota, growth kinetics, carcass attributes, and meat quality among fattening goats, underscoring the manifold impacts of forages on animal vitality and productivity [35].

Additionally, the accessibility and caliber of forages are pivotal considerations in feed formulation for dairy goat husbandry. Given the substantial heterogeneity in the nutritional profiles of forages, their nutritive potency can markedly sway the overall health and performance metrics

of dairy goats [31]. Adroit forage management practices encompassing selection, harvest, and storage regimes are indispensable for securing a reservoir of premium-grade forages conducive to dairy goat nutrition.

Supplements occupy a pivotal niche in the dietary mosaic of dairy goats, concomitantly bolstering milk quality, animal wellness, and overall productivity. The incorporation of supplements into dairy goat diets has undergone exhaustive scrutiny for its ramifications on milk production dynamics, nutrient utilization efficiencies, and animal welfare indices. An array of supplements ranging from fatty acids and microalgae to vitamins has been interrogated for their potential in enhancing the nutritional profile of milk, amplifying milk yields, and fortifying animal health.

Scholarly inquiry has delineated that the integration of fatty acid supplements into dairy goat diets orchestrates discernible modulations in milk lipid biosynthesis and lipolysis pathways, thereby effectuating shifts in milk fat contents and fatty acid spectra. Furthermore, the supplementation of microalgae in caprine diets has evinced augmentations in the concentrations of docosahexaenoic acid and total n-3 fatty acids in milk and cheese matrices, thereby accentuating the nutritional exquisiteness of milk.

Moreover, the supplementation regimen incorporating dietary L-carnitine has been associated with elevated blood carnitine levels in dairy goats, attesting to the potential of nutritional adjuncts in influencing metabolic dynamics and animal vitality. Concurrently, the incorporation of high-palmitic acid fat supplements has garnered attention for its purported efficacy in optimizing lactational performances among high-producing dairy goats, thereby underscoring the pivotal role of dietary fats in optimizing milk output.

Furthermore, the judicious utilization of supplements in dairy goat nutrition has been correlated with ameliorative shifts in milk yield, milk quality, and serum biochemical profiles. Scientific research has evidenced that the supplementation of ecotrofin™ engenders favorable outcomes on milk yield, milk quality, and serum biochemistry in lactating goats, thereby contributory to the amelioration of animal welfare and productivity.

By-products serve as formidable constituents in dairy goat nutrition, proffering a cornucopia of nutritional dividends and espousing tenets of sustainable agricultural practices. By-products stemming from sundry agricultural and industrial processes have been harnessed in dairy goat diets, furnishing an alternate reservoir of nutrients and redounding to the mitigation of waste burdens. The assimilation of by-products into dairy goat nutrition has been scrutinized for its ramifications on milk production dynamics, nutrient assimilation efficiencies, ruminal fermentation kinetics, and overarching animal health.

By-products such as pistachio remnants, dried distillers grains with solubles (DDGS), and dried citrus pulp (DCP) can be efficaciously assimilated into dairy goat diets, eliciting nuanced shifts in ruminal fermentation modalities, blood metabolic profiles, and milk fatty acid compositions [36]. Moreover, the harnessing of agricultural by-products has been probed for its influence on milk attributes, nutrient assimilation kinetics, ruminal fermentation cascades, and methane abatement in dairy goat cohorts, thus accentuating the potential of by-products in enhancing milk nutritional profiles and curtailing feeding overheads.

Furthermore, the incorporation of by-products into dairy goat nutrition has been conjoined with ameliorative transformations in milk technological indices, sensory attributes, and health dividends. Other research suggests that the inclusion of artichoke by-products in dairy goat rations precipitates salutary impacts on milk technological and sensory dimensions, fostering a reduction in feeding expenditures without compromising milk quality [37]. Additionally, the exploration of fermented goat dairy products has unearthed their putative health benefits, spanning anti-inflammatory, cardiovascular, and metabolic arenas, thereby catalyzing the emergence of novel dairy formulations enriched with enhanced nutritional and functional attributes [38].

Concentrates assume an indispensable mantle in undergirding the nutritional edifice and overall performance matrix of dairy goats. The integration of concentrates into dairy goat diets has been the subject of intensive inquiry, courtesy of its far-reaching repercussions on milk production, nutrient utilization kinetics, and animal health indices [39]. High-yielding dairy goats necessitate diets replete with copious starchy concentrates to underpin their energy requisites, particularly in attaining apogean lactational benchmarks [39].

Their inclusion in dairy goat diets engenders palpable effects on milk output, compositional nuances, and gustatory attributes, thus underscoring the pivotal role of concentrates in optimizing milk quality and yield [40]. The nutritional constitution intrinsic to concentrates markedly shapes the quality and constituents of goat milk. Research elucidation has probed into the fatty acid profiles, protein titres, and mineral compositions of goat milk in response to disparate concentrate formulations and dietary configurations, thereby accentuating the imprint of concentrates on milk nutritional profiles [41,42].

Moreover, the incorporation of concentrates has been correlated with discernible perturbations in ruminal microbiota, growth kinetics, carcass attributes, and meat quality among fattening goats, thus spotlighting the multifaceted impacts of concentrates on animal vigor and productivity [43]. Furthermore, the accessibility and caliber of concentrates assume paramount importance in feed formulation for dairy goat enterprises.

Given the marked heterogeneity in the nutritional spectra of concentrates, their nutritive valor can substantially sway the overall health and performance metrics of dairy goats [31]. Hence, judicious concentrate management encompassing selection, formulation, and feeding modalities emerges as quintessential for furnishing a reservoir of premium-grade concentrates conducive to dairy goat nutrition.

5. STRATEGIES FOR OPTIMIZING FEED FORMULATION

The strategic balancing of rations to meet the exacting nutritional requisites of dairy goats stands as a linchpin for optimizing milk production, animal vitality, and overall productivity. Achieving equilibrium in ration formulation mandates meticulous scrutiny of the nutrient profiles inherent to feed constituents, ensuring precise alignment with the dietary imperatives of dairy goats. This meticulous process constitutes a sine qua non for attaining peak milk yields, superior milk quality, and enhanced animal welfare.

Research underscores that the formulation of total mixed rations (TMR) necessitates judicious calibration to furnish a harmonious amalgam of metabolizable protein, minerals, and vitamins, thereby regulating energy intake and curtailing the total dry matter ingested by dairy goats [44]. Moreover, the meticulous balancing of rations sourced from a diverse array of locally available feeds reverberates in discernible alterations in greenhouse gas emissions stemming from dairy goat operations, thus accentuating the environmental ramifications of ration formulation [45].

Further research underscores the pivotal role of ration balancing in satisfying the protein and energy exigencies of lactating goats, alongside modulating nutritional metabolism during critical transitional phases [46,47]. The strategic harmonization of rations is inextricably linked to improved shifts in milk production, milk quality, and animal welfare, thereby underpinning augmented performance and productivity among dairy goats [47,48]. Additionally, the deployment of precision diet formulation and the nuanced balancing of rations to optimize essential amino acid ratios hold promise for bolstering net incomes and curbing environmental footprints in dairy farming milieus [49]. Moreover, the meticulous balancing of rations is allied with enhancements in nitrogen efficiency, nutrient uptake, and farm profitability within dairy goat production ecosystems [50].

In a complementary vein, the formulation of feeds tailored to augment digestibility and assimilation in dairy goats constitutes a cornerstone for optimizing milk production, nutrient uptake, and overall animal health. The discerning curation and balancing of feed constituents are pivotal for meeting the exacting nutritional demands of dairy goats and fostering efficient feed utilization.

Assorted investigations have probed into the impacts of diverse feed components and supplements on nutrient digestibility, rumen fermentation, and milk production in dairy goat populations.

For instance, the integration of mulberry leaf biomass into dietary regimens has evinced pronounced enhancements in fiber digestion and utilization, thereby eliciting superior lactational outcomes in both goats and dairy cattle [51]. Moreover, supplementation with fibrolytic enzymes has demonstrated efficacy in augmenting feed digestion and milk production in dairy cows [52]. Additionally, the inclusion of non-traditional feed ingredients such as tomato and cucumber waste fruits has evinced potential in efficaciously supplanting cereal-based concentrates in ruminant diets, thereby underscoring the efficiency of feed utilization [53].

Furthermore, the partial substitution of concentrate with feed blocks has been associated with ameliorations in nutrient utilization, microbial nitrogen flux, and milk yield and composition in goats [54]. Likewise, reductions in dietary crude protein levels have been shown to enhance nutrient digestion, serum metabolites, and nitrogen utilization in growing goat kids [55]. Notably, the compaction of complete feed pellets has been found to augment acceptability, digestibility, and nutrient utilization, thereby eliciting favorable shifts in animal performance [56].

Moreover, supplementation with glycerin has evinced efficacy in enhancing feed digestibility and bolstering microbial protein production in the rumen of cattle [57]. The incorporation of non-traditional feed resources such as *Azolla pinnata* and mango seeds has been found to heighten nutrient digestibility, milk yield, and feed conversion efficiency in dairy goats [58,59]. Additionally, the treatment of feed resources employing biochemical agents such as effective microbes and urea molasses has been demonstrated to enhance feed digestibility and nutritive value [60].

Addressing specific nutritional lacunae in dairy goats assumes paramount significance in safeguarding their health and optimizing productivity. Myriad investigations have delved into the repercussions of specific nutritional deficits and the potential ameliorative interventions to redress them. Notably, iron deficiency anemia (IDA) emerges as a pervasive nutritional shortfall globally, with research delineating the potential of fermented goat milk consumption to ameliorate brain molecular functions during IDA convalescence, thereby proffering salutary benefits in addressing this deficiency [61]. Furthermore, calcium-enriched goat's milk has been documented to expedite iron status recovery more efficaciously than calcium-enriched cow's milk in rats afflicted with nutritional ferropenic anemia, thus spotlighting the potency of specific dietary interventions in rectifying iron deficits [62].

Moreover, selenium deficiency looms as a recurrent concern in dairy goat husbandry, with supplementation utilizing barium selenate emerging as a recommended prophylactic measure for forestalling clinical mastitis and ameliorating milk quality in selenium-depleted locales [63]. Copper deficiency constitutes another salient nutritional apprehension, with studies documenting clinical manifestations of deficiency in both dairy goats and offspring, thereby underscoring the imperative of redressing specific mineral deficits in dairy goat nutrition [64].

Recently, gamut of alternative feed sources and supplements to enrich the nutritional caliber of dairy goat diets and bolster milk production were researched. For instance, the adjunct of vegetable oils to dairy goat diets has been demonstrated to elevate the lipid profile of milk and its derivatives, furnishing a viable alternative to supplemental feeding during the dry period [65]. Additionally, date fruit waste has been probed as a prospective feed alternative for lactating dairy goats, thus showcasing its viability for inclusion in dietary formulations [66].

Supplementation with glycerin has emerged as a promising energy feedstuff alternative for dairy animals, evincing potential benefits in augmenting milk composition and thermal stability in dairy goats [67]. Mineral blocks and other supplements have evinced utility in enhancing milk quality and amplifying the productivity of lactating goats [68]. Furthermore, the deployment of herbal feed additives has been shown to modulate intestinal lactic acid bacteria counts in dairy goats, potentially impacting their gastrointestinal health [69]. Additionally, dietary supplements such as zinc-methionine and L-carnitine have been scrutinized for their potential to elevate milk production and bolster resistance to udder stress in dairy goats [70]. Furthermore, sodium butyrate supplementation has been probed for its capacity to mitigate apoptosis induced by high-concentrate diets in mammary cells of dairy goats [71]. The incorporation of marine algae supplementation has been shown to amplify the docosahexaenoic acid (DHA) content in milk and favorably influence the n6 to n3 ratio in dairy goat populations [72].

6. CHALLENGES AND LIMITATIONS IN OPTIMIZING FEED FORMULATION

Fine-tuning feed formulation for dairy goats poses myriad challenges and constraints that exert pronounced effects on their nutritional status, well-being, and productivity. These challenges encompass heat stress, feed sorting phenomena, and the requisite for alternative feedstuffs and supplementary nutrients. Heat stress instances have been shown to curtail feed intake and compound issues stemming from diminished energy intake, thus exerting adverse ramifications on milk yield and animal welfare

[73]. Moreover, the incidence of feed sorting behaviors targeting shorter particles can engender diminished energy consumption, thereby further impinging upon the nutritional equilibrium of dairy goats [73].

Furthermore, the utilization of alternative feedstuffs and supplements can encounter impediments rooted in factors such as their availability, cost implications, and the exigency for addressing specific nutrient deficits. Environmental vicissitudes and managerial exigencies, typified by instances of heat stress, possess the capacity to disrupt feed intake and nutrient assimilation among dairy goats, thereby exerting tangible repercussions on their holistic health and productivity [3]. Additionally, the scarcity of high-yielding animals acclimated to local environments, dearth of premium-grade feeds, and logistical hurdles in transporting products to markets represent formidable challenges confronting dairy goat farmers across diverse locales, thereby encumbering their capacity to optimize feed formulation and elevate animal nutrition standards [74].

Furthermore, the imperative of remedying specific nutritional inadequacies, such as deficiencies in iron and selenium, poses formidable hurdles in devising diets attuned to the precise requisites of dairy goats [75]. The utilization of alternative feedstuffs and supplements is also circumscribed by considerations such as palatability, digestibility, and the potential for eliciting deleterious effects on milk composition and animal well-being. Additionally, the imperative of precision in formulating diets to align with the nuanced nutritional mandates of dairy goats engenders challenges in safeguarding optimal nutrient utilization and animal performance [76,77,78,79]. Moreover, the integration of supplements to redress specific nutritional lacunae may encounter constraints stemming from factors such as their availability, cost considerations, and potential interactions with other dietary constituents.

7. CONCLUSIONS

In conclusion, this review underscores the intricate interplay of genetic, environmental, and nutritional factors in optimizing feed formulation and management practices for dairy goats in intensive production systems.

Firstly, genetic factors significantly influence feed formulation strategies, as the genetic makeup of dairy goat breeds impacts milk production, composition, and overall productivity. Understanding genetic parameters and polymorphisms, such as those associated with milk protein fractions and yield, offers crucial insights into tailoring diets to specific breed requirements.

Secondly, environmental challenges, notably heat stress and fluctuating feed availability, pose substantial hurdles in achieving optimal nutrition and performance. Strategies to mitigate these challenges, including precision livestock farming and utilization of local by-products, are essential for maintaining herd health and productivity.

Thirdly, the review underscores the pivotal role of nutritional interventions, such as supplement utilization and alternative feed incorporation, in addressing specific deficiencies and enhancing overall performance. From fatty acid supplementation to herbal feed additives, a diverse array of strategies exists to optimize nutrient utilization and support dairy goat health.

Moreover, the review emphasizes the importance of precision and adaptability in feed formulation, considering factors like palatability, digestibility, and cost-effectiveness. Balancing rations to meet the evolving nutritional needs of dairy goats, particularly during critical transition stages, is paramount for sustaining productivity and profitability.

8. REFERENCES

- [1] Bouattour, M., Casals, R., Albanell, E., Such, X., & Caja, G. (2008). Feeding soybean oil to dairy goats increases conjugated linoleic acid in milk. *Journal of Dairy Science*, 91(6), 2399-2407. <https://doi.org/10.3168/jds.2007-0753>
- [2] Zhu, H., Ma, J., Du, R., Zheng, L., Wu, J., Song, W., ... & Hua, J. (2014). Characterization of immortalized dairy goat male germline stem cells (mgscs). *Journal of Cellular Biochemistry*, 115(9), 1549-1560. <https://doi.org/10.1002/jcb.24812>
- [3] Lu, C. and Miller, B. (2019). Current status, challenges and prospects for dairy goat production in the americas. *Asian-Australasian Journal of Animal Sciences*, 32(8), 1244-1255. <https://doi.org/10.5713/ajas.19.0256>
- [4] Bett, R., Kosgey, I., Kahi, A., & Peters, K. (2008). Analysis of production objectives and breeding practices of dairy goats in kenya. *Tropical Animal Health and Production*, 41(3), 307-320. <https://doi.org/10.1007/s11250-008-9191-9>
- [5] Romero-Huelva, M., Ramírez-Fenosa, M., Planelles-González, R., García-Casado, P., & Molina-Alcaide, E. (2017). Can by-products replace conventional ingredients in concentrate of dairy goat diet?. *Journal of Dairy Science*, 100(6), 4500-4512. <https://doi.org/10.3168/jds.2016-11766>
- [6] Tsiplakou, E., Kotrotsios, V., Hadjigeorgiou, I., & Zervas, G. (2010). Differences in sheep and goats milk fatty acid profile between conventional and organic farming systems. *Journal of Dairy Research*, 77(3), 343-349. <https://doi.org/10.1017/s0022029910000270>
- [7] Bampidis, V., Azimonti, G., Bastos, M., Dusemund, B., Durjava, M., Kouba, M., ... & Revez, J. (2022). Assessment of the efficacy of the feed additive consisting of *saccharomyces cerevisiae* cncm i-1077 (levucell® sc) for dairy cows, cattle for fattening, minor ruminant species and camelids (lallemand sas). *Efsa Journal*, 20(7). <https://doi.org/10.2903/j.efsa.2022.7431>
- [8] Leiber, F., Arnold, N., Heckendorn, F., & Werne, S. (2020). Assessing effects of tannin-rich sainfoin supplements for grazing dairy goats on feed protein efficiency. *Journal of Dairy Research*, 87(4), 397-399. <https://doi.org/10.1017/s0022029920000965>
- [9] Contreras-Jodar, A., Salama, A., Hamzaoui, S., Vailati-Riboni, M., Caja, G., & Loor, J. (2018). Effects of chronic heat stress on lactational performance and the transcriptomic profile of blood cells in lactating dairy goats. *Journal of Dairy Research*, 85(4), 423-430. <https://doi.org/10.1017/s0022029918000705>
- [10] Mosolov, A., Gorlov, I., Nikolaev, D., Slozhenkina, M., Kudryashova, O., & Vasilyeva, M. (2022). Ensuring environmental safety of goat milk production based on the integration of innovations in feeding. *Iop Conference Series Earth and Environmental Science*, 981(2), 022098. <https://doi.org/10.1088/1755-1315/981/2/022098>
- [11] Contreras-Jodar, A., Nayan, N., Hamzaoui, S., Caja, G., & Salama, A. (2019). Heat stress modifies the lactational performances and the urinary metabolomic profile related to gastrointestinal microbiota of dairy goats. *Plos One*, 14(2), e0202457. <https://doi.org/10.1371/journal.pone.0202457>
- [12] Contreras-Jodar, A., Salama, A., Hamzaoui, S., Vailati-Riboni, M., Caja, G., & Loor, J. (2018). Effects of chronic heat stress on lactational performance and the transcriptomic profile of blood cells in lactating dairy goats. *Journal of Dairy Research*, 85(4), 423-430. <https://doi.org/10.1017/s0022029918000705>
- [13] Hamzaoui, S., Caja, G., Such, X., Albanell, E., & Salama, A. (2020). Milk production and energetic metabolism of heat-stressed dairy goats supplemented with propylene glycol. *Animals*, 10(12), 2449. <https://doi.org/10.3390/ani10122449>
- [14] Evan, T., Carro, M., Yepes, J., Haro, A., Arbesú, L., Romero-Huelva, M., ... & Molina-Alcaide, E. (2020). Effects of feeding multinutrient blocks including avocado pulp and peels to dairy goats on feed intake and milk yield and composition. *Animals*, 10(2), 194. <https://doi.org/10.3390/ani10020194>
- [15] Salama, A., Caja, G., Albanell, E., Such, X., Casals, R., & Plaixats, J. (2003). Effects of dietary supplements of zinc-methionine on milk production, udder health and zinc metabolism in dairy goats. *Journal of Dairy Research*, 70(1), 9-17. <https://doi.org/10.1017/s0022029902005708>
- [16] Ghavipanje, N., Nasri, M., Farhangfar, S., Ghiasi, S., & Vargas-Bello-Pérez, E. (2021). Regulation of

- nutritional metabolism in transition dairy goats: energy balance, liver activity, and insulin resistance in response to berberine supplementation. *Animals*, 11(8), 2236. <https://doi.org/10.3390/ani11082236>
- [17] Nguyen, T., Chaiyabutr, N., Chanpongsang, S., & Thammacharoen, S. (2017). Dietary cation and anion difference: effects on milk production and body fluid distribution in lactating dairy goats under tropical conditions. *Animal Science Journal*, 89(1), 105-113. <https://doi.org/10.1111/asj.12897>
- [18] Pereira, G., Neto, J., Gracindo, Â., Silva, Y., Difante, G., Gurgel, A., ... & Lima, G. (2021). Replacement of grain maize with spineless cactus in the diet of dairy goats. *Journal of Dairy Research*, 88(2), 134-138. <https://doi.org/10.1017/s0022029921000352>
- [19] Bøe, K., Ehrlenbruch, R., & Andersen, I. (2011). The preference for water nipples vs. water bowls in dairy goats. *Acta Veterinaria Scandinavica*, 53(1). <https://doi.org/10.1186/1751-0147-53-50>
- [20] Hamzaoui, S., Salama, A., Albanell, E., Such, X., & Caja, G. (2013). Physiological responses and lactational performances of late-lactation dairy goats under heat stress conditions. *Journal of Dairy Science*, 96(10), 6355-6365. <https://doi.org/10.3168/jds.2013-6665>
- [21] Scholtens, M., Lopez-Villalobos, N., Garrick, D., Blair, H., Lehnert, K., & Snell, R. (2019). Genetic parameters for total lactation yields of milk, fat, protein, and somatic cell score in new zealand dairy goats. *Animal Science Journal*, 91(1). <https://doi.org/10.1111/asj.13310>
- [22] Xiong, J., Bao, J., Hu, W., Shang, M., & Zhang, L. (2023). Whole-genome resequencing reveals genetic diversity and selection characteristics of dairy goat. *Frontiers in Genetics*, 13. <https://doi.org/10.3389/fgene.2022.1044017>
- [23] Lashmar, S., Visser, C., & Marle-Köster, E. (2016). Snp-based genetic diversity of south african commercial dairy and fiber goat breeds. *Small Ruminant Research*, 136, 65-71. <https://doi.org/10.1016/j.smallrumres.2016.01.006>
- [24] Anggraeni, A., Syifa, L., Sari, O., Ishak, A., & Sumantri, C. (2021). Polymorphism of csnl1 (g.12164g>a) and csnl2 (g.8913c>a) genes in pure and cross dairy goats. *Bio Web of Conferences*, 33, 02001. <https://doi.org/10.1051/bioconf/20213302001>
- [25] Mastrangelo, S., Sardina, M., Tolone, M., & Portolano, B. (2013). Genetic polymorphism at the csnl1 gene in girgentana dairy goat breed. *Animal Production Science*, 53(5), 403. <https://doi.org/10.1071/an12242>
- [26] Wang, G., Pi, X., Ji, Z., Qin, Z., Hou, L., Chao, T., ... & Wang, J. (2015). Investigation of the diversity and origins of chinese dairy goats via the mitochondrial dna d-loop. *Journal of Animal Science*, 93(3), 949. <https://doi.org/10.2527/jas.2014-8420>
- [27] McLaren, A., Mucha, S., Mrode, R., Coffey, M., & Conington, J. (2016). Genetic parameters of linear conformation type traits and their relationship with milk yield throughout lactation in mixed-breed dairy goats. *Journal of Dairy Science*, 99(7), 5516-5525. <https://doi.org/10.3168/jds.2015-10269>
- [28] Kahi, A. and Wasike, C. (2019). Dairy goat production in sub-saharan africa: current status, constraints and prospects for research and development. *Asian-Australasian Journal of Animal Sciences*, 32(8), 1266-1274. <https://doi.org/10.5713/ajas.19.0377>
- [29] Romero-Huelva, M., Ramírez-Fenosa, M., Planelles-González, R., García-Casado, P., & Molina-Alcaide, E. (2017). Can by-products replace conventional ingredients in concentrate of dairy goat diet?. *Journal of Dairy Science*, 100(6), 4500-4512. <https://doi.org/10.3168/jds.2016-11766>
- [30] Sejian, V., Silpa, M., Nair, M., Devaraj, C., Krishnan, G., Bagath, M., ... & Bhatta, R. (2021). Heat stress and goat welfare: adaptation and production considerations. *Animals*, 11(4), 1021. <https://doi.org/10.3390/ani11041021>
- [31] Paskas, S., Miocinovic, J., Vojnovic, B., & Bicskei, Z. (2019). The nutritional quality of feedstuffs used in dairy goat nutrition in vojvodina. *Biotechnology in Animal Husbandry*, 35(2), 163-178. <https://doi.org/10.2298/bah1902163p>
- [32] Chilliard, Y. and Ferlay, A. (2004). Dietary lipids and forages interactions on cow and goat milk fatty acid composition and sensory properties. *Reproduction Nutrition Development*, 44(5), 467-492. <https://doi.org/10.1051/rnd:2004052>
- [33] Min, B., Hart, S., Sahlu, T., & Satter, L. (2005). The effect of diets on milk production and composition, and on lactation curves in pastured dairy goats. *Journal of Dairy Science*, 88(7), 2604-2615. [https://doi.org/10.3168/jds.s0022-0302\(05\)72937-4](https://doi.org/10.3168/jds.s0022-0302(05)72937-4)
- [34] Bonanno, A., Grigoli, A., Montalbano, M., Bellina, V., Mazza, F., & Todaro, M. (2013). Effects of diet on casein and fatty acid profiles of milk from goats differing in genotype for α s1-casein synthesis. *European Food Research and Technology*, 237(6), 951-963. <https://doi.org/10.1007/s00217-013-2069-8>
- [35] Wu, Z., Yang, X., Zhang, J., Wang, W., Liu, D., Hou, B., ... & Xia, Y. (2023). Effects of forage type on the rumen microbiota, growth performance, carcass traits,

- and meat quality in fattening goats. *Frontiers in Veterinary Science*, 10. <https://doi.org/10.3389/fvets.2023.1147685>
- [36] Ghaffari, M., Tahmasbi, A., Khorvash, M., Naserian, A., & Vakili, A. (2013). Effects of pistachio by-products in replacement of alfalfa hay on ruminal fermentation, blood metabolites, and milk fatty acid composition in saanen dairy goats fed a diet containing fish oil. *Journal of Applied Animal Research*, 42(2), 186-193. <https://doi.org/10.1080/09712119.2013.824889>
- [37] Muelas, R., Monllor, P., Romero, G., Sayas-Barberá, E., Navarro, C., Díaz, J., ... & Sendra, E. (2017). Milk technological properties as affected by including artichoke by-products silages in the diet of dairy goats. *Foods*, 6(12), 112. <https://doi.org/10.3390/foods6120112>
- [38] Chen, L., Bagnicka, E., Chen, H., & Shu, G. (2023). Health potential of fermented goat dairy products: composition comparison with fermented cow milk, probiotics selection, health benefits and mechanisms. *Food & Function*, 14(8), 3423-3436. <https://doi.org/10.1039/d3fo00413a>
- [39] Levesque, J., Dion, S., Rico, D., Brassard, M., Gervais, R., & Chouinard, P. (2022). Milk yield and composition in dairy goats fed extruded flaxseed or a high-palmitic acid fat supplement. *Journal of Dairy Research*, 89(4), 355-366. <https://doi.org/10.1017/s0022029922000784>
- [40] Chilliard, Y., Ferlay, A., Rouel, J., & Lamberet, G. (2003). A review of nutritional and physiological factors affecting goat milk lipid synthesis and lipolysis. *Journal of Dairy Science*, 86(5), 1751-1770. [https://doi.org/10.3168/jds.s0022-0302\(03\)73761-8](https://doi.org/10.3168/jds.s0022-0302(03)73761-8)
- [41] Gebereyowhans, S. (2023). Inclusion of microalgae in the caprine diet improves nutritional profile of milk and its camembert cheese. *International Journal of Dairy Technology*, 76(4), 801-812. <https://doi.org/10.1111/1471-0307.12994>
- [42] Miroshina, T. and Chalova, N. (2023). Dairy goat breeding in russia and the world (review). *E3s Web of Conferences*, 380, 01004. <https://doi.org/10.1051/e3sconf/202338001004>
- [43] Musco, N., Morittu, V., Mastellone, V., Spina, A., Vassalotti, G., D'Aniello, B., ... & Lombardi, P. (2021). Effects of ecotrofin™ on milk yield, milk quality and serum biochemistry in lactating goats. *Journal of Animal Physiology and Animal Nutrition*, 105(S1), 26-33. <https://doi.org/10.1111/jpn.13592>
- [44] Drackley, J. and Cardoso, F. (2014). Prepartum and postpartum nutritional management to optimize fertility in high-yielding dairy cows in confined tmr systems. *Animal*, 8, 5-14. <https://doi.org/10.1017/s1751731114000731>
- [45] Broderick, G. (2018). Review: optimizing ruminant conversion of feed protein to human food protein. *Animal*, 12(8), 1722-1734. <https://doi.org/10.1017/s1751731117002592>
- [46] Aguilera, J., Prieto, C., & Fonolla, J. (1990). Protein and energy metabolism of lactating granadina goats. *British Journal of Nutrition*, 63(2), 165-175. <https://doi.org/10.1079/bjn19900104>
- [47] Ghavipanje, N., Nasri, M., Farhangfar, S., Ghiasi, S., & Vargas-Bello-Pérez, E. (2021). Regulation of nutritional metabolism in transition dairy goats: energy balance, liver activity, and insulin resistance in response to berberine supplementation. *Animals*, 11(8), 2236. <https://doi.org/10.3390/ani11082236>
- [48] Berthel, R., Simmler, M., Dohme-Meier, F., & Keil, N. (2022). Dairy sheep and goats prefer the single components over the mixed ration. *Frontiers in Veterinary Science*, 9. <https://doi.org/10.3389/fvets.2022.1017669>
- [49] Binggeli, S., Lapierre, H., Charbonneau, E., Ouellet, D., & Pellerin, D. (2021). Economic and environmental effects of revised metabolizable protein and amino acid recommendations on canadian dairy farms. *Journal of Dairy Science*, 104(9), 9981-9998. <https://doi.org/10.3168/jds.2020-19893>
- [50] Fadul-Pacheco, L., Pellerin, D., Chouinard, P., Wattiaux, M., Duplessis, M., & Charbonneau, E. (2017). Nitrogen efficiency of eastern canadian dairy herds: effect on production performance and farm profitability. *Journal of Dairy Science*, 100(8), 6592-6601. <https://doi.org/10.3168/jds.2016-11788>
- [51] Hassan, F., Arshad, M., Li, M., Rehman, M., Loor, J., & Huang, J. (2020). Potential of mulberry leaf biomass and its flavonoids to improve production and health in ruminants: mechanistic insights and prospects. *Animals*, 10(11), 2076. <https://doi.org/10.3390/ani10112076>
- [52] Yang, W., Beauchemin, K., & Rode, L. (1999). Effects of an enzyme feed additive on extent of digestion and milk production of lactating dairy cows. *Journal of Dairy Science*, 82(2), 391-403. [https://doi.org/10.3168/jds.s0022-0302\(99\)75245-8](https://doi.org/10.3168/jds.s0022-0302(99)75245-8)
- [53] Romero-Huelva, M., Ramos-Morales, E., & Molina-Alcaide, E. (2012). Nutrient utilization, ruminal fermentation, microbial abundances, and milk yield and composition in dairy goats fed diets including tomato and cucumber waste fruits. *Journal of Dairy Science*, 95(10), 6015-6026. <https://doi.org/10.3168/jds.2012-5573>

- [54] Molina-Alcaide, E., Morales-García, Y., Martín-García, A., Salem, H., Nefzaoui, A., & Sanz-Sampelayo, M. (2010). Effects of partial replacement of concentrate with feed blocks on nutrient utilization, microbial n flow, and milk yield and composition in goats. *Journal of Dairy Science*, 93(5), 2076-2087. <https://doi.org/10.3168/jds.2009-2628>
- [55] Zhu, W., Xu, W., Wei, C., Zhang, Z., Jiang, C., & Chen, X. (2020). Effects of decreasing dietary crude protein level on growth performance, nutrient digestion, serum metabolites, and nitrogen utilization in growing goat kids (*capra. hircus*). *Animals*, 10(1), 151. <https://doi.org/10.3390/ani10010151>
- [56] Patil, P., Gendley, M., Dubey, M., Dhok, A., Gade, N., & Khune, V. (2023). Effect of feeding gram straw-based complete feed pellets on the performance, nutrient utilization and rumen fermentation of goats. *Asian Journal of Dairy and Food Research*, (Of). <https://doi.org/10.18805/ajdfr.dr-2031>
- [57] Chanjula, P., Pakdeechanuan, P., & Wattanasit, S. (2014). Effects of dietary crude glycerin supplementation on nutrient digestibility, ruminal fermentation, blood metabolites, and nitrogen balance of goats. *Asian-Australasian Journal of Animal Sciences*, 27(3), 365-374. <https://doi.org/10.5713/ajas.2013.13494>
- [58] Hassanein, H., Maggiolino, A., El-Fadel, M., Palo, P., El-Sanafawy, H., Hussein, A., ... & Salem, A. (2023). Inclusion of azolla pinnata as an unconventional feed of zaraibi dairy goats, and effects on milk production and offspring performance. *Frontiers in Veterinary Science*, 10. <https://doi.org/10.3389/fvets.2023.1101424>
- [59] El-Sanafawy, H., Maggiolino, A., El-Esawy, G., Riad, W., Zeineldin, M., Abdelmegeid, M., ... & Salem, A. (2023). Effect of mango seeds as an untraditional source of energy on the productive performance of dairy damascus goats. *Frontiers in Veterinary Science*, 10. <https://doi.org/10.3389/fvets.2023.1058915>
- [60] Mekuriaw, S., Tsunekawa, A., Ichinohe, T., Tegegne, F., Haregeweyn, N., Kobayashi, N., ... & Fievez, V. (2020). Effect of feeding improved grass hays and eragrostis tef straw silage on milk yield, nitrogen utilization, and methane emission of lactating fogera dairy cows in ethiopia. *Animals*, 10(6), 1021. <https://doi.org/10.3390/ani10061021>
- [61] Moreno-Fernandez, J., López-Aliaga, I., García-Burgos, M., Alférez, M., & Díaz-Castro, J. (2019). Fermented goat milk consumption enhances brain molecular functions during iron deficiency anemia recovery. *Nutrients*, 11(10), 2394. <https://doi.org/10.3390/nu11102394>
- [62] Nestares, T., Barrionuevo, M., Díaz-Castro, J., López-Aliaga, I., Alferez, M., & Campos, M. (2008). Calcium-enriched goats' milk aids recovery of iron status better than calcium-enriched cows' milk, in rats with nutritional ferropenic anaemia. *Journal of Dairy Research*, 75(2), 153-159. <https://doi.org/10.1017/s0022029908003178>
- [63] Sánchez, J., Montes, P., Jiménez, A., & Andrés, S. (2007). Prevention of clinical mastitis with barium selenate in dairy goats from a selenium-deficient area. *Journal of Dairy Science*, 90(5), 2350-2354. <https://doi.org/10.3168/jds.2006-616>
- [64] Almeida, V., Lima, T., Filho, G., Bom, H., Fonseca, S., Evêncio-Neto, J., ... & Mendonça, F. (2022). Copper deficiency in dairy goats and kids. *Pesquisa Veterinária Brasileira*, 42. <https://doi.org/10.1590/1678-5150-pvb-7162>
- [65] Medeiros, E., Queiroga, R., Oliveira, M., Medeiros, A., Sabedot, M., Bomfim, M., ... & Madruga, M. (2014). Fatty acid profile of cheese from dairy goats fed a diet enriched with castor, sesame and faveleira vegetable oils. *Molecules*, 19(1), 992-1003. <https://doi.org/10.3390/molecules19010992>
- [66] Yuniarti, E., Evvyernie, D., & Astuti, D. (2015). Production and energy partition of lactating dairy goats fed rations containing date fruit waste. *Media Peternakan*, 39(1), 27-33. <https://doi.org/10.5398/medpet.2016.39.1.27>
- [67] Thoh, D., Pakdeechanuan, P., & Chanjula, P. (2017). Effect of supplementary glycerin on milk composition and heat stability in dairy goats. *Asian-Australasian Journal of Animal Sciences*, 30(12), 1711-1717. <https://doi.org/10.5713/ajas.17.0066>
- [68] Noor, M., Rusli, N., Mat, K., Hasnita, C., & Mira, P. (2020). Milk composition and milk quality of saanen crossbreed goats supplemented by mineral blocks. *Tropical Animal Science Journal*, 43(2), 169-175. <https://doi.org/10.5398/tasj.2020.43.2.169>
- [69] Foksowicz-Flaczyk, J., Wójtowski, J., Dankow, R., Mikołajczak, P., Pikul, J., Gryszczyńska, A., ... & Stanisławski, D. (2022). The effect of herbal feed additives in the diet of dairy goats on intestinal lactic acid bacteria (lab) count. *Animals*, 12(3), 255. <https://doi.org/10.3390/ani12030255>
- [70] Salama, A., Caja, G., Albanell, E., Such, X., Casals, R., & Plaixats, J. (2003). Effects of dietary supplements of zinc-methionine on milk production, udder health and zinc metabolism in dairy goats. *Journal of Dairy Research*, 70(1), 9-17. <https://doi.org/10.1017/s0022029902005708>

- [71] Chang, G., Yan, J., Ma, N., Liu, X., Dai, H., Bilal, M., ... & Shen, X. (2018). Dietary sodium butyrate supplementation reduces high-concentrate diet feeding-induced apoptosis in mammary cells in dairy goats. *Journal of Agricultural and Food Chemistry*, 66(9), 2101-2107.
<https://doi.org/10.1021/acs.jafc.7b05882>
- [72] Nudda, A., Cannas, A., Correddu, F., Atzori, A., Lunesu, M., Battacone, G., ... & Pulina, G. (2020). Sheep and goats respond differently to feeding strategies directed to improve the fatty acid profile of milk fat. *Animals*, 10(8), 1290.
<https://doi.org/10.3390/ani10081290>
- [73] Mehaba, N., Salama, A., Such, X., Albanell, E., & Caja, G. (2019). Lactational responses of heat-stressed dairy goats to dietary l-carnitine supplementation. *Animals*, 9(8), 567.
<https://doi.org/10.3390/ani9080567>
- [74] Liang, J. and Paengkoum, P. (2019). Current status, challenges and the way forward for dairy goat production in asia – conference summary of dairy goats in asia. *Asian-Australasian Journal of Animal Sciences*, 32(8), 1233-1243.
<https://doi.org/10.5713/ajas.19.0272>
- [75] Battini, M., Barbieri, S., Vieira, A., Stilwell, G., & Mattiello, S. (2016). Results of testing the prototype of the awin welfare assessment protocol for dairy goats in 30 intensive farms in northern italy. *Italian Journal of Animal Science*, 15(2), 283-293.
<https://doi.org/10.1080/1828051x.2016.1150795>
- [76] Goetsch, A. (2019). Recent advances in the feeding and nutrition of dairy goats. *Asian-Australasian Journal of Animal Sciences*, 32(8), 1296-1305.
<https://doi.org/10.5713/ajas.19.0255>
- [77] Gheorghe-Irimia, R. A., Tăpăloagă, D., Tăpăloagă, P. R., Ilie, L. I., Şonea, C., Serban, A. I. (2022). Mycotoxins and Essential Oils—From a Meat Industry Hazard to a Possible Solution: A Brief Review. *Foods*, 11(22), 3666.
- [78] Tudor, L., Pițuru, M. T., Gheorghe-Irimia, R. A., Şonea, C., & Tăpăloagă, D. (2023). Optimizing milk production, quality and safety through essential oil applications. *Farmacia*, 71(5)
- [79] Irimia, R. A., Georgescu, M., Tudoreanu, L., & Militaru, M. (2020). Testing The Effect Of Nigella Sativa Essential Oil Solution On Chicken Breast pH And Total Volatile Base Nitrogen During Refrigeration. *Scientific Works. Series C, Veterinary Medicine*, 66(2).