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EcoAgriTourism, in the light of its multidisciplinary character, is a wide-open journal which brings together the opinions of specialists from both academic and economic environment, fostering fruitful collaborations.

The journal's structure covers all aspects of the fields approached, the focus being on original and current researches with applications in agriculture, food industry and rural tourism. Collaborators may feel free to undertake biological and technical aspects as well as aspects with social, cultural and environmental impact. Information of general interest is also welcome for the agriecology-food-tourism axis

Prof. Romulus Gruia Ph. D.

The Journal of EcoAgroTurism aims at approaching analyses, methodologies, options and references within the journal's framework.



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Eco-Agri-Tourism and the Overlapping Crises of Today's World

In a society adrift, food and tourism are among the first casualties. Unfortunately, the world today is caught in significant societal turmoil, and neither Europe nor Romania is exempt. Concerns about sustainability and the role of eco-tourism and agri-rural tourism in restoring this process have become a core recurring theme in our publication.

In brief, we believe these concerns are justified, given the overlapping crises of this decade. Only by “inventorying” these crises can we grasp the surrounding complexity and gravity. Solutions to these issues are possible if they are acknowledged and analyzed both systematically and in detail, making it crucial to highlight them, as we do in the **box below**, as an initial step in raising awareness for the eco-agri-tourism sector.

PROBLEM GROUP	TYPOLGY OF POTENTIAL CRISES	SPECIFICATION
Delayed Reforms and Resolutions	➤ The ecological and climate change crisis	- A zero-priority issue
	➤ The democracy crisis and systemic reforms	- even at the European level, but especially in Romania: dysfunctions in education and vocational training, in the healthcare system, as well as reforms in justice
	➤ Societal imbalances	- culture, religion, ethnicity, gender
Intensified European Issues	➤ The immigration crisis and the European integration model	- unresolved social issues, with growing negative effects;
	➤ The crisis of European institutions and the issue of state reform	- Romania's compatibility through major state reforms
	➤ The competitiveness crisis	- in many economic sectors, the United States and China have pulled ahead of Europe
Geopolitical Turmoil	➤ The geopolitical security crisis	- military conflicts aimed at changing the world order, to the detriment of democracy
	➤ The demographic crisis	- demographic imbalances in certain regions of the globe and uncontrolled population migration
	➤ The food and biodiversity crisis	- caused by the drastic reduction of fertile agricultural land and climate changes

All we have left is the hope of somewhat avoiding the mentioned crises, to give a real chance to agri-tourism and the joy of savoring natural landscapes through eco-tourism.

Director of the publication,
Prof. Romulus GRUIA, PhD,
PhD supervisor, Scientific Leader

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WALNUT CHEESE-LIKE ALTERNATIVES AS AN INNOVATION AMONG DAIRY ANALOGUES

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Abstract: The plant-based cheese alternatives (PBCAs) category displayed 51% growth in sales in the US between 2019 and 2022, with the market in Europe showing sales growth of 23% in 2022. Different approaches and ingredients can be employed to design PBCAs to dairy food products with enhanced nutritional value. The aim of this study was to understand the effects of the addition of walnut oil, inactive yeast and different ratio of walnuts/water, used to develop the walnut based milk, on key physicochemical properties and quality attributes of walnut cheese-like formulations. Development and optimization of the formula and technology for a walnut cheese-like alternatives was performed using STAT-EASE 360 software. This study also included the development of technological diagrams of the product formulations, analysis of the physicochemical parameters such as pH, total acidity, water activity, total polyphenol content and antioxidant activity. Based on the obtained data, the studied formulations were compared with each other, as well as with the control sample. The results of this work will help in understanding the role of different amounts of walnut oil, instant yeast and walnuts/water ratio in formulating walnut cheese-like alternatives with improved nutritional profile and the impact thereof on relevant physicochemical properties and antioxidant potential.

Keywords: walnuts, plant-based cheese alternatives, product formulation and optimization, quality evaluation.

1. Introduction

The interest in plant-based foods designed to provide an alternative to cheese products is increasing, with the global market for such products growing at a compound annual growth rate (CAGR) of 7.6% from 2016 to 2024, and is expected to reach a value of almost \$4 billion by 2024 [1, 2].

Some plant-based products have been consumed for centuries as traditional foods in many cultures (e.g., tofu and sufu), and have been studied extensively [3]. Soy is used worldwide to produce various plant-based products and factors including coagulant type and concentration, temperature and time have been investigated to improve the structural development of soy-based products [4].

Other raw materials employed for the production of plant-based foods intended as alternatives to cheese products are nuts, such as cashews, macadamias and almonds [5]. Various vegetable oils (coconut, palm, or

sunflower), starches, and polysaccharides (carrageenan, xanthan gum, and guar gum) are employed to enhance the texture, stability, and melting properties of plant-based alternative food products [6, 7].

Walnut (*Juglans regia* L) is a potential ingredient for plant-based cheese alternative formulations. Walnut a member of Juglandaceae family and is one of the finest nuts of temperate regions. It is the oldest cultivated fruit in the world [8]. Walnut kernel is prized as a specially nut because of its potential health benefits and organoleptic properties. The health benefits of walnut kernel are usually attributed to its chemical composition [9].

A combination of walnuts/water ratio, walnut oil and instant yeast has not previously been applied through response surface methodology (RSM) to enhance the quality and antioxidant potential of plant-based cheese alternative. Therefore, the study objective was to use RSM to develop a plant-based cheese-like alternative, using as a main raw material walnuts (*Juglans*

regia L.), optimize its ingredients and process conditions, as well as analyze its physicochemical parameters and antioxidant potential.

2. Materials and methods

2.1. Materials

Raw walnuts, instant yeast, agar-agar, walnut oil, salt and sugar were procured from the local market in Chisinau, Moldova. All chemicals used within this study were purchased from Eco-Chimie and Sigma-Aldrich (Chisinau, Moldova). All the chemicals used were of HPLC or

analytical grade. Distilled water was used throughout.

2.2. Experimental design

A Box–Behnken experimental design [10] was used for product optimisation and consisted of the manufacture of 20 different formulations (Table 1). Three independent factors were applied: A - walnuts/water ration (0.14 – 0.33 c.u.) used for walnut milk preparation, B - different amounts of walnut oil (13 – 17 %) and C - instant yeast (1.5 – 2.5%). The measured response variables included pH, water activity, total acidity content, DPPH radical scavenging activity and total polyphenol content.

Table 1. Experimental design

Formulation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Independent factors																				
Walnuts/Water ratio, [c. u.]	0.24	0.24	0.14	0.24	0.24	0.24	0.33	0.24	0.33	0.24	0.39	0.14	0.24	0.24	0.24	0.33	0.14	0.07	0.14	0.33
Walnut oil, [%]	15.0	15.0	17.0	15.0	15.0	15.0	17.0	18.4	13.0	15.0	15.0	13.0	15.0	11.6	15.0	17.0	13.0	15.0	17.0	13.0
Instant yeast, [%]	2.0	2.0	2.5	2.0	2.0	2.8	2.5	2.0	1.5	2.0	2.0	2.5	2.0	2.0	1.2	1.5	1.5	2.0	1.5	2.5

2.3. Walnut milk preparation

Walnut milk preparation was carried out essentially following the procedure: walnuts cleaning, soaking, peeling, coarse grinding, extraction at 35-40 °C, decantation, homogenization [11]. Five samples of walnut milk with different ratio of walnuts/water were obtained in accordance with experimental design (Table 1).

2.4. Walnut cheese-like alternative preparation

Walnut cheese-like alternatives formulations with the composition presented in Table 2 were prepared, taking into account experimental design developed for the current study.

Table 2. Base formulation

No	Ingredient	%
1	Walnut milk	79
2	Walnut oil	15
3	Instant yeast	2
4	Agar-agar	1.5
5	Salt	1.5
6	Sugar	1

All ingredients were weighed (according to the experimental design), combined and whisked in a

blender for about 3 minutes until a homogeneous mass was formed. After the mass was boiled for 5 minutes until it became thicker.

Special forms were filled with the prepared mass to 2-3 cm height, closed, and left at room temperature for 2 h for cooling (Fig. 1). Subsequently, forms were placed in the refrigerator for 12 h and after walnut cheese-like alternatives were used for analysis.



Fig. 1. Experimental sample of walnut cheese-like alternative

2.5. pH, water activity and total acidity content

The pH was measured using a digital pH meter (WTW INOLAB 7110p, Germany), water activity was determined using a water activity analyzer LabSwift-aw (Novasina AG, Switzerland). Both methods are described by Grasso N. et al. [1] Total acidity (TA) was evaluated using the protocol, described by Fabiszewska A. et al. [12]

2.6. Antioxidant potential analysis

2.6.1. DPPH assay

The radical scavenging activity of walnut cheese-like alternative formulations were studied in terms of radical scavenging ability using the stable DPPH[•] method [13, 14]. Briefly, 0.1 ml of the sample was added to 3.9 ml of 60 µM solution of DPPH[•] in methanol.

The reaction was carried in dark and the absorbance was recorded at 515 nm to determine the concentration of remaining DPPH[•]. Methanol as instead of DPPH[•] solution was used as blank solution. The values of [DPPH[•]]_t at each reaction time were calculated according to the standard curve. Concentration range of DPPH was of 0.38-38 µg/ml ($A_{515\text{ nm}} = 0.0293 [\text{DPPH}^{\bullet}]_t - 0.0072$), where the concentration [DPPH[•]]_t is expressed in µg/ml).

The coefficient of linear correlation of the above relation is $R = 0.9999$. The radical scavenging activity was calculated using the equation:

$$\text{RSA} = 100\% \cdot ([\text{DPPH}^{\bullet}]_0 - [\text{DPPH}^{\bullet}]_{30}) / [\text{DPPH}^{\bullet}]_0$$

where [DPPH[•]]₀ is the concentration of the DPPH[•] solution (without sample) at $t=0$ min and [DPPH[•]]₃₀ is the remained DPPH[•] concentration at $t=30$ min. Lower [DPPH[•]]_t in the reaction mixture indicates higher free radical scavenging activity.

2.6.2. Total polyphenol content

For quantification of total polyphenol content, the Folin-Ciocalteu's method was used [15]. A volume of 0.5 ml of Folin-Ciocalteu's reagent was added to a dark flask, containing 0.5 ml of

the each formulation and 10 ml of distilled water. After 5 min, 8 ml of a 7.5% aqueous sodium carbonate solution was added to the mixture and the content was mixed thoroughly.

The samples were kept in dark for 2h and then the absorbance was measured at 765 nm with HACH LANGE DR-5000 UV/vis spectrophotometer. Three parallel samples were analysed.

Gallic acid was used for constructing the standard curve, obtained in advance. Concentration range of gallic acid was of 0.05-0.5 mg/ml. The results of total polyphenol content were expressed as mg of gallic acid equivalents per ml of extract (mg GAE/ml).

2.7. Statistical analysis

The software STAT-EASE 360 was used for the experimental design which consisted of 20 formula combinations (Table 1). For the product optimization, Response surface methodology (RSM) was used. Both the independent variables and responses were fitted to the quadratic model by performing the analysis of variance (ANOVA).

The experimental results were analysed to determine the lack of fit and the significance of the quadratic model and the effect of interaction between the independent variables and responses. The statistical significance of the terms in the regression equations was examined by ANOVA for each response and the significance test level was set at 5% ($P < 0.05$).

3. Results and discussions

3.1. pH, water activity and total acidity content evaluation

The determination of water activity (a_w), pH and total acidity (TA) in the developed walnut cheese-like alternatives was made in order to control its quality and safety.

Experimental values of a_w , pH and TA in all 21 formulations of walnut cheese-like alternatives are presented in table 3.

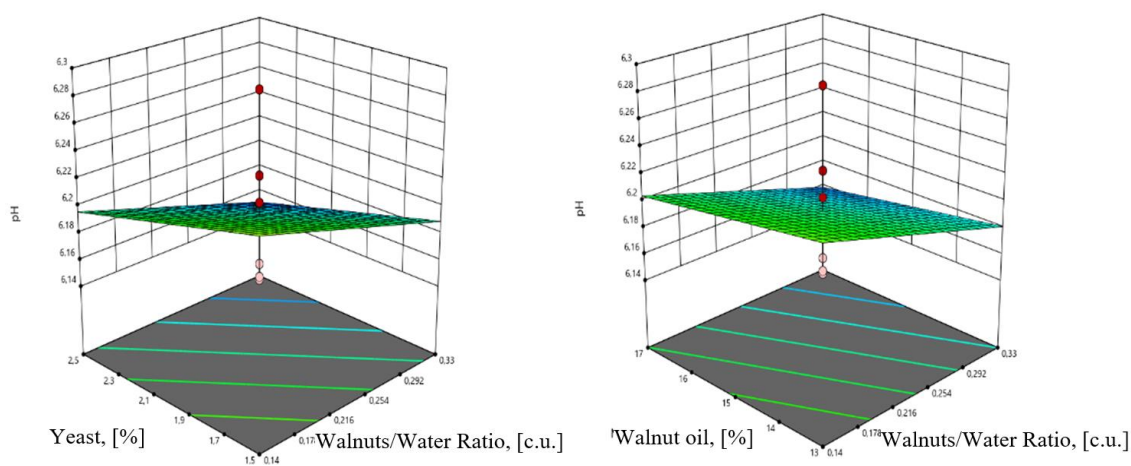
pH values in evaluated walnut cheese-like alternatives varied between 6.141 ± 0.001 and 6.285 ± 0.003 c.u.

Table 3. Effect of different walnut cheese-like alternatives formulations on the water activity (a_w), pH and total acidity (TA)

Formulation	Independent factors			Response variables		
	Walnut/ water ratio, [c.u.]	Walnut oil, [%]	Instant yeast, [%]	a_w	pH	TA, [T°]
1	0.24	15.0	2.0	0.778±0.01	6.203±0.001	9.51±0.02
2	0.24	15.0	2.0	0.778±0.03	6.285±0.003	10.52±0.04
3	0.14	17.0	2.5	0.777±0.01	6.201±0.001	9.51±0.02
4	0.24	15.0	2.0	0.772±0.05	6.223±0.005	8.57±0.02
5	0.24	15.0	2.0	0.766±0.03	6.157±0.003	9.51±0.02
6	0.24	15.0	2.8	0.768±0.01	6.144±0.001	9.02±0.02
7	0.33	17.0	2.5	0.777±0.05	6.148±0.005	10.50±0.04
8	0.24	18.4	2.	0.779±0.03	6.173±0.001	10.03±0.01
9	0.33	13.0	1.5	0.779±0.05	6.195±0.003	8.04±0.01
10	0.24	15.0	2.0	0.779±0.01	6.147±0.005	9.50±0.04
11	0.39	15.0	2.0	0.770±0.03	6.141±0.001	8.50±0.02
12	0.14	13.0	2.5	0.784±0.01	6.185±0.005	9.05±0.01
13	0.24	15.0	2.0	0.782±0.01	6.145±0.003	8.01±0.01
14	0.24	11.6	2.0	0.779±0.05	6.238±0.001	11.03±0.02
15	0.24	15.0	1.2	0.779±0.03	6.220±0.005	8.07±0.04
16	0.33	17.0	1.5	0.779±0.01	6.195±0.003	9.51±0.01
17	0.14	13.0	1.5	0.778±0.03	6.247±0.001	8.53±0.02
18	0.07	15.0	2.0	0.776±0.03	6.250±0.003	8.03±0.04
19	0.14	17.0	1.5	0.777±0.01	6.196±0.005	8.05±0.02
20	0.33	13.0	2.5	0.780±0.03	6.160±0.001	11.01±0.04
21	-	-	-	0.780±0.01	6.410±0.001	8.03±0.01

According to plant-based cheese alternatives this value should be no more than 7.3. The

experimental data regarding pH in all walnut cheese-like alternatives are shown in Figure 2.



$$\text{pH} = 6.19 - 0.0230 \cdot A - 0.0195 \cdot B - 0.0114 \cdot C$$

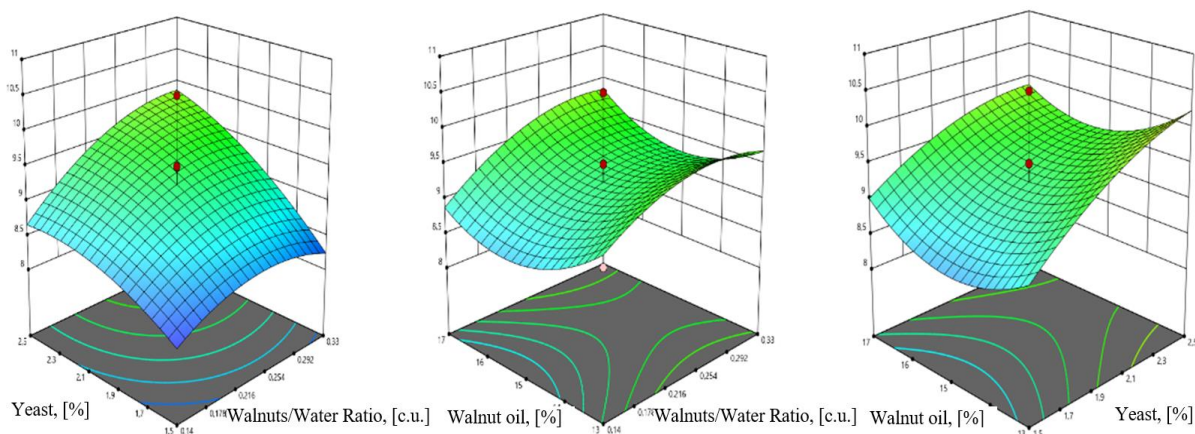
Fig. 2. Effect of different walnut cheese-like alternatives formulations on the pH values

Total acidity in walnut cheese-like alternatives was evaluated to find out the level of acidity of the developed formulations, which can affect the taste, consistency and texture of the analyzed

formulations. The values of total acidity in all 21 formulations varied between 8.0 ± 0.01 and 11.0 ± 0.01 T°. Total acidity being 8.0 ± 0.01 T° in the control sample. The experimental data on

total acidity (Figure 3) indicate that the total acidity in all 20 walnut cheese-like alternatives

are in correspondence with the optimal indicator for the plant-based dairy products (16-18 T°).



$$TA = 9.24 + 0.3545 \cdot A + 0.5625 \cdot B - 0.0499 \cdot C + 0.25 \cdot A \cdot B + 0.125 \cdot A \cdot C - 0.125 \cdot B \cdot C - 0.3162 \cdot A^2 - 0.2279 \cdot B^2 + 0.4792 \cdot C^2$$

Fig. 3. Effect of different walnut cheese-like alternatives formulations on the total acidity content

Water activity evaluation allows to verify the safety level of the developed product. The water activity values of 21 studied walnut cheese-like

formulations varied between 0.772 ± 0.05 and 0.784 ± 0.01 c.u. (Figure 4).

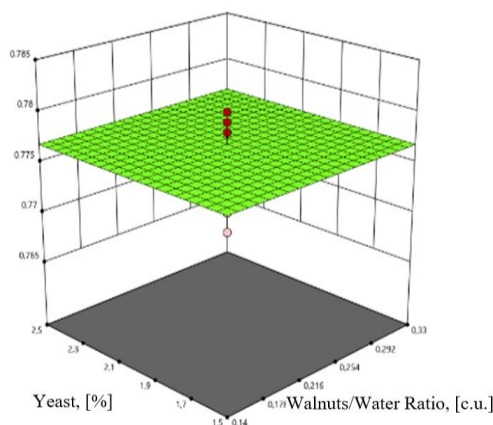


Fig. 4. Effect of different walnut cheese-like alternatives formulations on the water activity values

Based on this data, it follows that the developed walnut cheese-like alternatives refer to the food products with an medium water content. The recommended water activity in plant-based milk cheese alternatives is around 0.85 to 0.95 c.u., but it can vary from the composition and the manufacturing process.

3.2. Antioxidant potential evaluation

The antioxidant potential of polyphenol compounds in all 21 formulations of walnut cheese-like alternatives were evaluated. These data can help to understand the biological value of newly created food product. Experimental values of total polyphenol content and DPPH antioxidant activity are presented in Table 4.

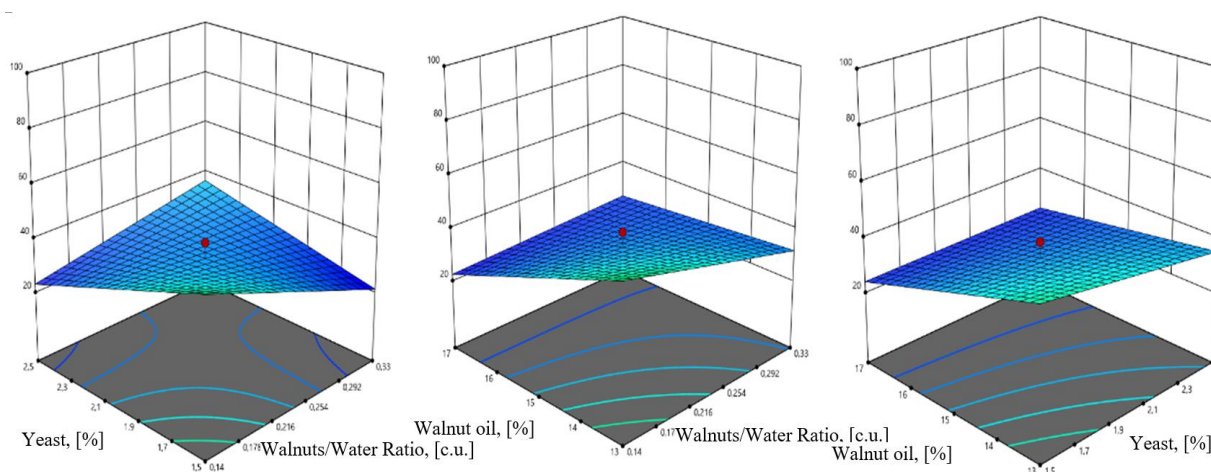
The DPPH antioxidant activity of walnut cheese-like alternatives was evaluated in order to assess the ability of the newly developed food product to protect the cells in human body from the action of free radicals. Free radicals are molecules that can lead to cell damage and accelerate aging. Determination of antioxidant activity in food products helps consumers to choose products that can influence in a positive way their health.

The formulation No. 17 had the maximum value of antioxidant activity being $94.47 \pm 0.05\%$, the formulation No. 2 had the lowest antioxidant activity of $22.26 \pm 0.03\%$. In the reference sample, this value was 2.24%.

Table 4. Effect of different walnut cheese-like alternatives formulations on the radical scavenging activity (DPPH) and total polyphenol content (TPC)

Formulation	Independent factors			Response variables	
	Walnut/water ratio, [c.u.]	Walnut oil, [%]	Instant yeast, [%]	DPPH, [%]	TPC, [mg/ml]
1	0.24	15.0	2.0	26.49±0.01	0.57±0.02
2	0.24	15.0	2.0	22.26±0.03	0.62±0.06
3	0.14	17.0	2.5	28.90±0.02	0.55±0.01
4	0.24	15.0	2.0	23.37±0.01	0.53±0.05
5	0.24	15.0	2.0	26.16±0.03	0.42±0.08
6	0.24	15.0	2.8	26.32±0.02	0.49±0.01
7	0.33	17.0	2.5	25.08±0.03	0.47±0.05
8	0.24	18.4	2.	22.58±0.01	0.40±0.06
9	0.33	13.0	1.5	25.08±0.02	0.52±0.02
10	0.24	15.0	2.0	26.58±0.03	0.52±0.02
11	0.39	15.0	2.0	23.77±0.05	0.64±0.04
12	0.14	13.0	2.5	31.48±0.02	0.51±0.02
13	0.24	15.0	2.0	38.68±0.01	0.57±0.01
14	0.24	11.6	2.0	35.81±0.03	0.53±0.02
15	0.24	15.0	1.2	29.60±0.01	0.48±0.01
16	0.33	17.0	1.5	32.68±0.02	0.55±0.02
17	0.14	13.0	1.5	94.47±0.05	0.46±0.03
18	0.07	15.0	2.0	31.76±0.05	0.45±0.04
19	0.14	17.0	1.5	26.49±0.02	0.41±0.01
20	0.33	13.0	2.5	57.41±0.05	0.60±0.04
21	-	-	-	2.24±0.01	0.11±0.03

In other walnut cheese-like alternatives formulations the value of antioxidant activity was considerably higher, compared to the reference sample (Figure 5).



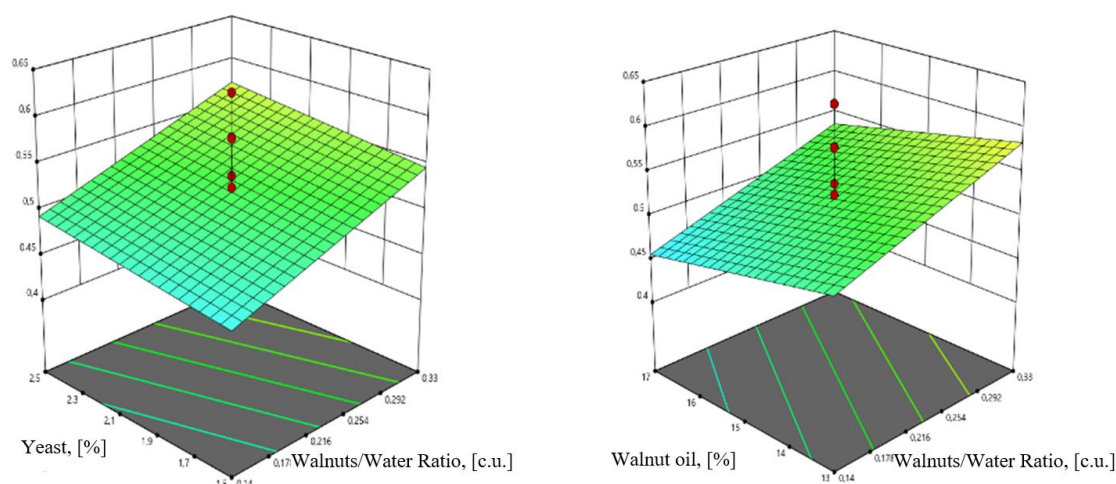
$$\text{DPPH} = 32.75 - 3.99 \cdot A - 3.03 \cdot B - 8.61 \cdot C + 10.66 \cdot A \cdot B + 5.73 \cdot A \cdot C + 3.18 \cdot B \cdot C$$

Fig. 5. Effect of different walnut cheese-like alternatives formulations on the DPPH radical scavenging activity

Total polyphenol content was evaluated in order to estimate its antioxidant potential that can bring benefits for human health, due to special polyphenols properties to protect cells from

damage caused by free radicals. Experimental values with TPC in all 21 formulations of walnut cheese-like alternatives are presented in Figure 6 and are in the range of 0.40±0.06 and 0.64±0.04

mg/ml. In the reference sample, this value was determined as 0.11 ± 0.03 mg/ml.



$$\text{TPC} = 0.5196 + 0.0397 \cdot A + 0.0131 \cdot B - 0.0240 \cdot C$$

Fig. 6. Effect of different walnut cheese-like alternatives formulations on the total polyphenol content

4. Conclusions

Response surface methodology was successfully used to develop walnut cheese-like alternatives and the results indicated that the main independent factor that significantly ($P < 0.05$) influenced the assessed response variables of the cheese-like formulations was walnut/water ratio, used for walnut milk preparation. The product optimisation carried out maximising the quality properties indicated that the best formulation to obtain walnut cheese-like alternatives was walnuts/water ratio (1/2.56), walnut oil amount (12%) and instant yeast concentration (1.5%).

It is important to note that the aim of this research was not just to replicate plant-based cheese, but to use its methods to create a new product with a unique quality parameters and nutritional value. The results of this research are an important step in developing innovative food products for consumers who want to avoid animal products [16-18]. These walnut cheese-like alternatives offer new options for vegetarians, improving the range and quality of plant-based diet choices.

Acknowledgement

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THE IMPORTANCE OF WOODY BIOMASS IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Abstract: Biomass is a primary carbon source alongside other renewable energy source. It can be used a raw material for the production of energy, biofuels and bio-chemical fuels in order to achieve energy independence for the region or country. The calorific value of wood varies between 15480 and 19440 kJ/kg depending on species and moisture content. Thermochemical conversion technologies such as pyrolysis, gasification and thermal processing, together with biomass co-generation in coal-fired power plants, could play an important role in thermal power generation. The carbon dioxide emissions from burning 1 kg of biomass replaces 0.33 cubic meters of methane gas, 0.74 kg of coal, 0.47 kg of petroleum fuel. The estimated annual amount of wood biomass that could be produced by introducing energy crops would be 7200-320000 tons /year for area of 21000 hectares. Traditional biomass, wood charcoal, agricultural residues are used for cooking and water heating.

Keywords: lower caloric power, biomass, wood, pellets

1. Introduction

Biomass fuels are valued by researchers because they reduce harmful emissions of fossil fuels into the atmosphere. Biomass torrefaction achieves superior thermal properties to solid biomass fuel, similar to those of fuel oil.

The torrefaction process achieves the following:

- decreasing the moisture content of the fuel;
- increasing the calorific value;
- creating a hydrophobic fuel that reabsorbs a small moisture content.

In the first treatment temperature range (100 °C, at atmosphere pressure), the water content of the wood is removed. When the temperature is between 100 – 250°C, heat absorption and degradation of the chemical composition of the wood occurs. In the third phase, which is encountered between 250 and 350°C, complete degradation of hemicellulose occurs. In the temperature range 330 - 370°C cellulose destruction occurs.

The fifth stage occurs often 350°C, this is when mangal (charcoal) is produced which is a degradation product of the lignin in the wood mass. Mass loss is an essential indicator of the torrefaction effect of wood.

The melting process is a thermo-chemical process carried out in the temperature range

between 200 and 300 °C in a atmosphere with oxygen or inert nitrogen and low heating rate.

The heat treatment process causes a chain of chemical process that can lead to a significant increase in energy density (2-19%) and in the calorific value of woody species (1-25%).

Heat treatment is important in lowering transport and storage biomass in large quantities. Torrefaction is used to modify the properties of wood or biomass and to make it easier to prepare it for thermo-chemical treatment.

An important aspect of bioethanol producing is the degradation processes of hemicelluloses, cellulose and lignin. During heat treatment of biomass, hemicellulose decomposes in the temperature range 200 - 280°C, cellulose decomposes between 240 and 350°C, lignin decomposes between 280 and 500°C.

2. Materials and method

Determination of the amount of heat resulting from the combustion of unit mass of a fuel is carried out with the calorimetric pump.

The calorific value of the fuel is measured with a calorimetric pump.

The Berthelot calorimeter is often usual, it consists of the following component (fig.1) is:

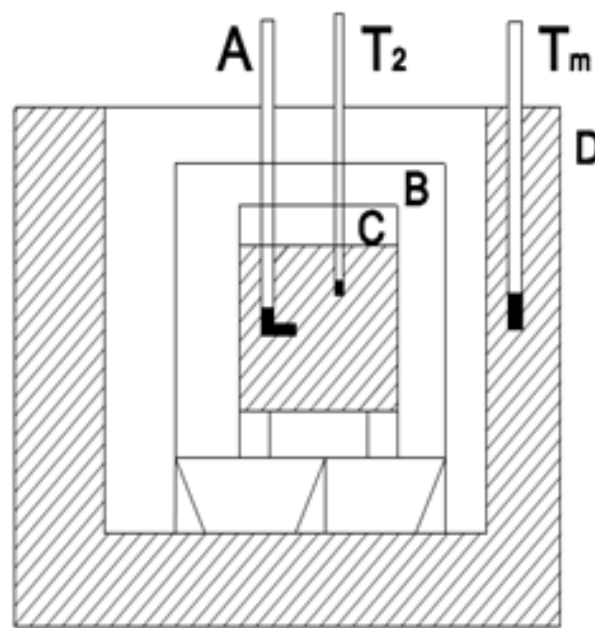


Fig. 1. Berthelot calorimeter

C- cylindrical vessel;

T₂-thermometer which is inserted into the vessel;

A-agitator.

The calorimeter operates on the mixing principle. The calorific value of wood can be determined by the method of determining the calorific value of chemical elements as a function of moisture content using Nadejin's relationship.

The method of determining the calorific value on the basis of each chemical element in wood is proposed by Mendelev, using the relations bellow:

$$GWP = [8100 C + 3400 (H + O/8 - 600 (U - 9 \cdot H))] / 0.23884 \text{ [kJ/kg]}$$

waves:

C, H, O - precents of the total mass of the chemical elements [kg];

U- moisture content [kg/kg].

$$ICP = 81 \cdot C + 246 \cdot H - 26 (O - S) - 6 \cdot W / 0.23884$$

waves:

C, H, O, S, W - percentage content of chemical components in fuels.

The test for determining the calorific value contains three distinct periods (Fig.2).

- The initial period (fore), which aims to determine the temperature variations, of the water in the calorimeter, due to the exchange of heat with the outside before;

- The main period begins with the ignition of the sample and has a consequence the increase of the water temperature in the calorimetric vessel due to the burning of the wood particle and the emanation of heat;

- The final period aims to determine the average temperature variation of the water in the calorimeter due to the heat exchange with the outside, after combustion.

For the poplar pellets U= 0%, m= 0.7000 g, higher caloric power= 18897 kJ/kg, lower caloric power= 18427 kJ/kg, energy density = 11.88 kJ/cm³, burning speed = 512 kJ/min, U= 10%, m= 0.8600 g, higher caloric power= 16889 kJ/kg, lower caloric power= 16151 kJ/kg, energy density = 12.63 kJ/kg, burning speed = 490 kJ/kg, U= 20%, m= 0.7930 g, higher caloric power= 15117 kJ/kg, lower caloric power= 13641 kJ/kg, energy density = 9.83 kJ/kg, burning speed = 298 kJ/kg, U=50%, m= 0.8320 g, higher caloric power= 9799 kJ/kg, lower caloric power= 6109 kJ/kg, energy density = 4.62 kJ/cm³, burning speed = 82 kJ/kg.

Fig. 2. Description of the calorific power determination process

The variation of the energy density and burning speed for poplar pellets is presented in Fig. 3.

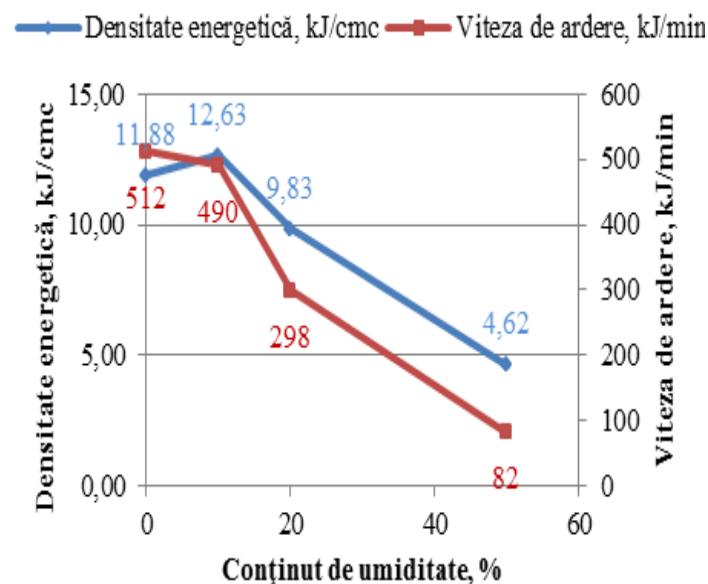


Fig. 3. The variation of the energy density for poplar pellets

For the beech pellets $U = 0\%$, $m = 0.6100$ g, higher calorific power = 18646 kJ/kg, lower calorific power = 18055 kJ/kg, energy density = 10.18

kJ/cm³, burning speed = 350 kJ/min, $U = 10\%$, $m = 0.5600$ g, higher calorific power = 16633 kJ/kg, lower calorific power = 15896 kJ/kg, energy

density = 8.09 kJ/kg, burning speed = 308 kJ/kg, U= 20%, m= 0.8080 g, higher caloric power= 14916 kJ/kg, lower caloric power= 13443 kJ/kg, energy density = 9.87 kJ/kg, burning speed = 272 kJ/kg, U=50%, m= 0.5140 g, higher caloric power= 9765 kJ/kg, lower caloric power= 6082

kJ/kg, energy density = 2.84 kJ/cm³, burning speed = 43 kJ/kg.

The variation of the energy density and burning speed for beech pellets is presented in Fig. 4.

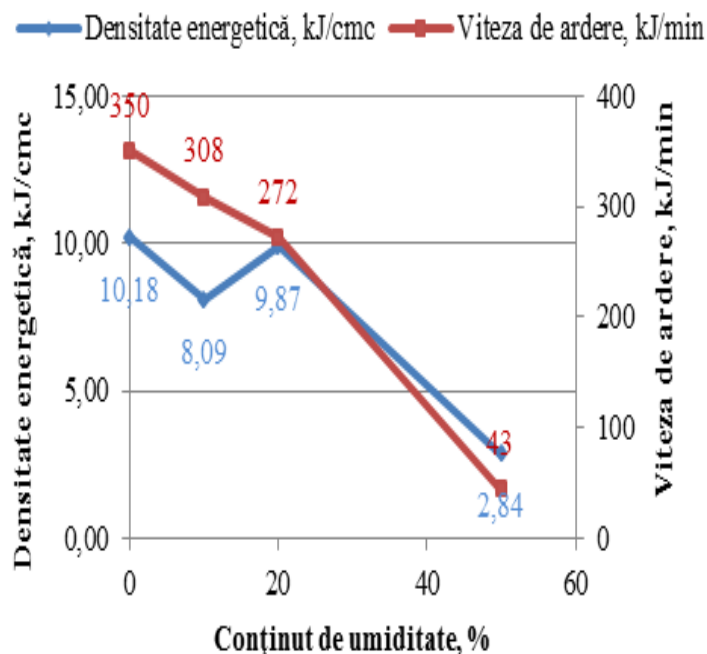


Fig. 4. The variation of the energy density for beech pellets

4. Conclusions

Today's economic market is faced with dwindling fossil fuel resources. In principle, greenhouse gases and harmful emissions must also be taken into account, thereby increasing the use of biomass as an energy source. Biomass material produces a large amount of energy, which can be made available to any consumer. For example, the Lower Calorific Value (LHV) of wood varies between 15480 and 19440 kJ/kg (4300 and 5400 kWh/t), depending on the species and moisture content of the material used as solid fuel. Biomass may have a potential of 14% of the world's total energy.

The unfavorable physical properties of biomass use, dictated also by large storage spaces, further compromise the economic use of biomass as feedstock. In addition, storing a large amount of wet biomass will further increase costs through the high rate of dry matter loss due to microbial activity and the danger of self-ignition.

The quality of products obtained from vegetable and wood biomass is difficult to define, but is very important from the point of view of

both the producer and the consumer of finished products.

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DIGITALIZING AGRI-FOOD LOGISTICS IN MOUNTAIN AREAS: OPPORTUNITIES AND CHALLENGES

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Abstract: The paper addresses the unique challenges of mountain farms from a food safety perspective and proposes innovative solutions based on the implementation of hygienic design principles. These farms play a vital role in food production in isolated regions but face significant vulnerabilities, including water contamination, poor hygiene, extreme weather conditions, and limited infrastructure. The paper identifies the risks associated with food safety in mountain farms. It analyzes practical solutions, such as Hygienic Design, to reduce contamination. Relevant case studies are presented to demonstrate the impact of the implemented solutions. Reducing contamination risks is highlighted through a decrease in food contamination rates by up to 30% in the analyzed farms, which increased product shelf life. The modernization of infrastructure and the use of durable materials allowed for efficient cleaning of equipment, reducing raw material losses by up to 25%. Products from farms that implemented Hygienic Design obtained eco-certifications, facilitating access to international markets. Barriers include high implementation costs and lack of access to adequate funding. The lack of technical training for farmers complicates the application of solutions. The limited infrastructure of mountain areas complicates the transport of perishable products. Subsidizing investments in infrastructure and modern equipment is essential. Organizing courses for farmers on hygiene and food safety best practices is necessary. Promoting international partnerships for the exchange of best practices can facilitate the implementation of solutions. The paper concludes that the implementation of Hygienic Design principles and support from authorities can transform mountain farms into examples of sustainability and food safety. Developing personalized guidelines and using advanced technologies are future research directions that can contribute to extending these benefits.

Keywords: Hygienic Design, Mountain Farms, Food Safety

1. Introduction

1.1. Context and Relevance

The Importance of Food Safety in Mountain Farms

Food safety is an essential priority in ensuring the well-being of the population, preventing foodborne illnesses, and maintaining a sustainable economy [1]. Mountain farms play a crucial role in food production in isolated regions, where access to industrial resources is limited. However, these farms face unique challenges related to food safety, driven by geographical conditions, inadequate infrastructure, and a lack of modern technology. In this context, implementing practices that ensure food safety in a mountain environment is vitally important for consumer protection and maintaining quality standards [5].

Mountain farms are located in regions with high altitudes and challenging terrain, characterized by variable climates, limited accessibility, and restricted infrastructure [2]. These farms are essential for local communities and play a significant role in preserving agricultural traditions, conserving biodiversity, and producing authentic foods such as dairy, meat, and honey [3, 6]. However, geographical isolation and lack of access to modern resources create vulnerabilities in ensuring food safety [4].

The main risks associated with mountain farms include:

- **Water contamination:** Water sources can be affected by human and animal activities, such as intensive grazing or improper waste disposal [7].

- **Poor hygiene:** Unsanitary conditions in processing and storage areas can increase the risk of food contamination [7].
- **Extreme weather conditions:** Climate changes can impact the quality and safety of raw materials [8].
- **Limited infrastructure:** Unpaved roads and a lack of transport facilities reduce the farms' ability to deliver safe food in a timely manner [6].

Challenges Related to Food Safety in Mountain Farms

- **Biological and Chemical Contamination**

Mountain farms are more susceptible to biological (bacteria, viruses, parasites) and chemical contamination (heavy metals, pesticides). Difficult hygiene conditions and the lack of modern technologies favour the occurrence of such contamination [9].

Example: Studies show that in mountainous areas with limited access to potable water, the rate of *E. coli* contamination is significantly higher than in other agricultural regions [10].

Inadequate Storage and Processing

Mountain farms often rely on improvised storage spaces that do not meet the required standards for temperature and humidity. Perishable products, such as milk and meat, can be compromised if not handled properly [7, 18].

Limited Access to Training and Regulations

Many mountain farmers lack access to training on food safety or are unaware of international standards. This lack of knowledge contributes to the perpetuation of unsafe practices [11].

Climate Change and Seasonal Variability

The phenomenon of climate change affects crop predictability and product quality, increasing the risk of contamination through flooding or drought [12].

2. Solutions for Improving Food Safety in Mountain Farms

2.1. Implementation of Hygienic Design Concepts

Hygienic Design refers to the design of equipment and facilities used in the food industry to prevent product contamination and facilitate efficient cleaning. According to EHEDG Document 8, the fundamental principles include [13]:

- **Suitable Materials:** Use of materials compatible with food products, resistant

to corrosion, and that do not transfer unwanted substances into the food [14].

- **Smooth and Non-Absorbent Surfaces:** Surfaces must be easy to clean and prevent the accumulation of contaminants [14, 19].
- **Accessibility for Cleaning and Inspection:** Equipment should be designed so that all areas are easily accessible for cleaning and inspection [15, 20].
- **Efficient Drainage:** The design should allow complete removal of liquids to prevent stagnant water accumulation [14].
- **Avoidance of Retention Areas:** Minimizing corners, cracks, and joints that could retain food residues or moisture [15].

Applicable International Standards

Several international standards regulate Hygienic Design principles:

- **EHEDG (European Hygienic Engineering and Design Group):** Provides detailed guidelines for the hygienic design of equipment and factories in the food industry. EHEDG Document 8 serves as the basis for evaluating hygienic design in the EHEDG equipment certification program [13].
- **ISO 22000:** An international standard specifying requirements for a food safety management system, integrating HACCP principles and good hygiene practices [16].
- **Codex Alimentarius:** A collection of internationally adopted standards, guidelines, and codes of practice aimed at protecting consumer health and ensuring fair practices in the food trade [17].

Economic and Safety Benefits

The implementation of Hygienic Design principles provides numerous benefits (Fig. 1):

- **Improved Food Safety:** Reduces the risk of product contamination, protecting consumer health.
- **Increased Operational Efficiency:** Hygienically designed equipment is easier and faster to clean, reducing downtime and associated costs.
- **Enhanced Equipment Durability:** Proper materials and design extend

equipment lifespan, reducing the need for frequent replacements.

- **Compliance with Regulations:** Ensures adherence to international standards and regulations, avoiding potential penalties or product recalls.
- **Enhanced Reputation:** Companies prioritizing Hygienic Design demonstrate a commitment to quality and safety,

strengthening consumer and business partner trust.

Adopting Hygienic Design not only protects public health but also optimizes production processes, providing a competitive advantage in the market.

Benefits of Implementing Hygienic Design

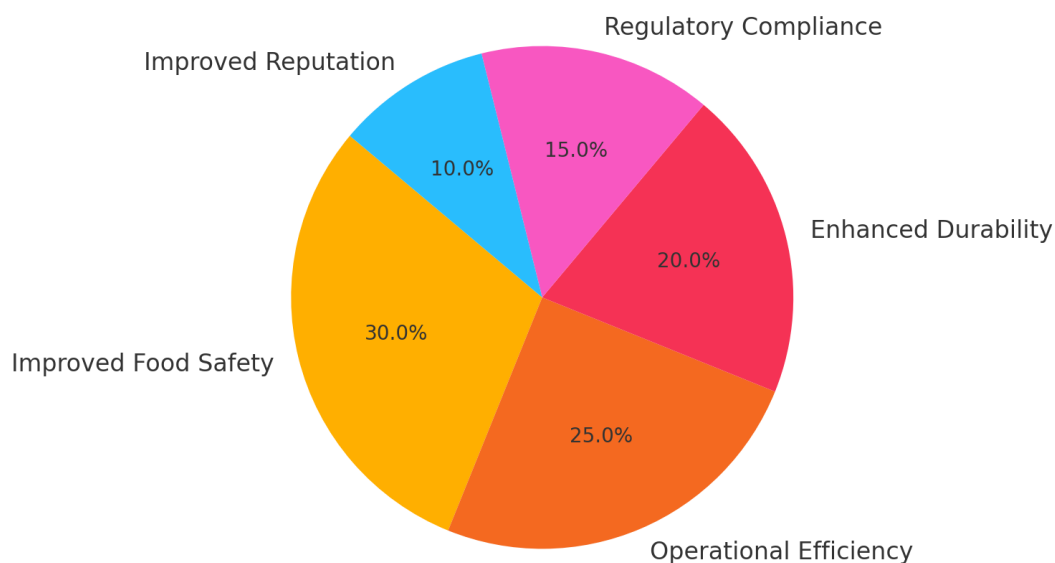


Fig. 1. *Benefits of Implementing Hygienic Design*

2.2. Access to Modern Technologies
Modern technologies can facilitate food safety in isolated environments. Examples include:

- Sensors for monitoring temperature and humidity in storage spaces.
- The use of drones to transport food samples to laboratories for rapid analysis.

2.3. Farmer Education

Organizing workshops and courses on food safety is crucial for mountain farmers. These training sessions should include:

- Methods to prevent biological and chemical contamination.
- The importance of personal and equipment hygiene.
- Compliance with international food safety regulations.

2.4. Government Support and Public Policies
Authorities should support mountain farms by:

- Subsidizing infrastructure modernization.

- Financing programs for the purchase of equipment that complies with hygiene standards.
- Creating local distribution networks to reduce delivery times for perishable foods.

2.5. Regional and International Cooperation

Partnerships with other farms, universities, and international organizations can facilitate access to resources, technologies, and best practices. For example, experience exchanges with mountain farms in Switzerland or Austria can provide applicable solutions for similar contexts.

3. Methodology

The research methods used included:

- Direct observations in mountain farms.
- Interviews with farmers and food safety specialists.

- Comparative analysis of current practices against hygienic design standards.

4. Case Studies: Mountain Farms in Romania

4.1. Valea Lupului Farm (Braşov County)

This small farm, located at an altitude of over 1,200 meters, specializes in the production of traditional milk and cheese. In 2022, the farmers implemented an automated cleaning system for milking equipment, reducing the risk of

contamination with pathogenic bacteria. Additionally, the milk processing facilities were modernized with easy-to-clean materials such as stainless steel, and the workflow was reorganized to separate clean and dirty areas.

Impact:

- A 30% reduction in contamination in the first year after implementation.
- A 20% increase in the shelf life of dairy products due to improved hygiene.

Table 1. Performance Indicators for HD Implementation at Valea Lupului Farm (Braşov County)

Performance Indicator	Before Implementation (2021)	After Implementation (2022)
Contamination Rate (%)	10%	7%
Product Validity Period (days)	10	12
Monthly Production Volume (litres)	5.000	5.500
Number of Customer Complaints	15	5

4.2. The Farm in Țara Moşilor (Alba County)

This farm is renowned for the production of organic honey and aged cheese, combining traditional methods with modern technologies. Through a project funded by the European Union, the farm installed rapid water testing stations used in processing, eliminating the risks of microbiological contamination.

Applied Innovations:

- Introduction of processing equipment compliant with EHEDG standards.

- Implementation of a temperature and humidity monitoring system for storage spaces.

Results:

- A 15% increase in production due to reduced losses.
- Certification of products as organic, which opened access to international markets.

Table 2. Performance Indicators for HD Implementation at the Țara Moşilor Farm (Alba County)

Performance Indicator	Before Implementation (2021)	After Implementation (2022)
Contamination Rate (%)	12%	8%
Product Validity Period (days)	7	10
Monthly Production Volume (litres)	4.500	5.200
Number of Customer Complaints	20	7

4.3. The Izvorul Muntelui Farm (Neamţ County)

Specializing in meat and meat product production, this farm has invested in modernizing slaughterhouse facilities, using materials approved for the food industry. The farm also implemented an organic waste management system to reduce environmental contamination risks.

Additional Efforts:

- Establishment of a meat processing unit equipped with state-of-the-art equipment.

- Organization of training sessions for employees on personal hygiene and the proper use of equipment.

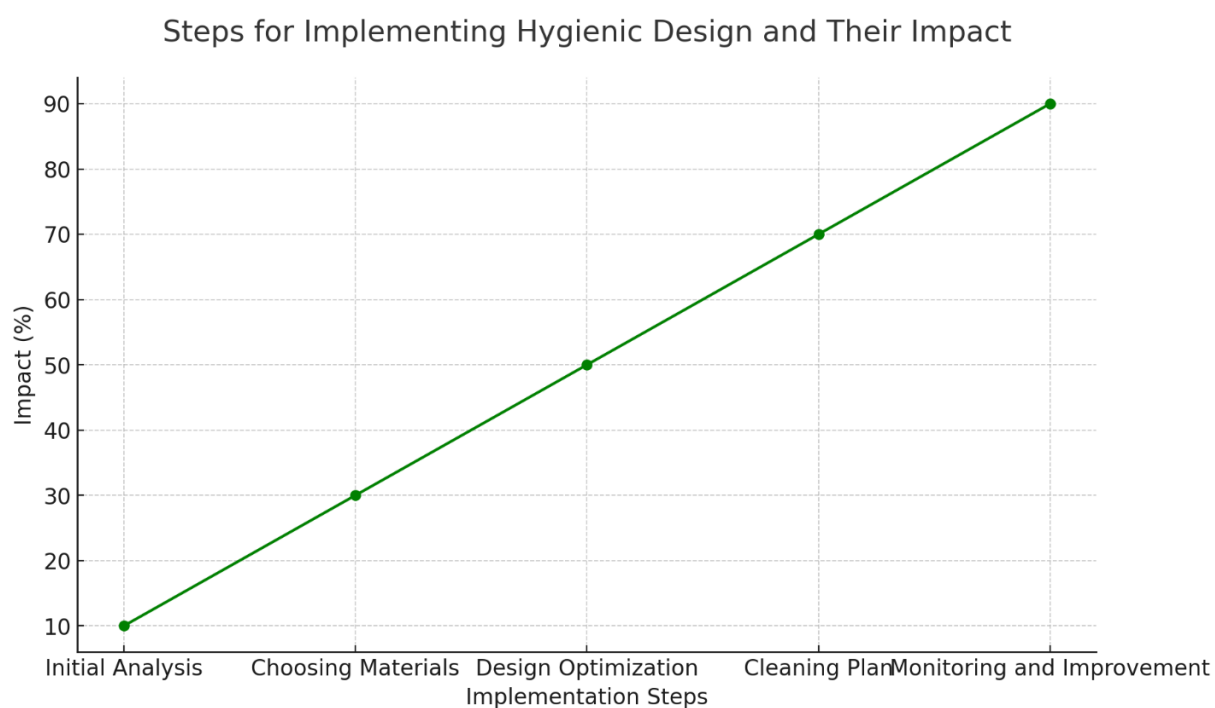
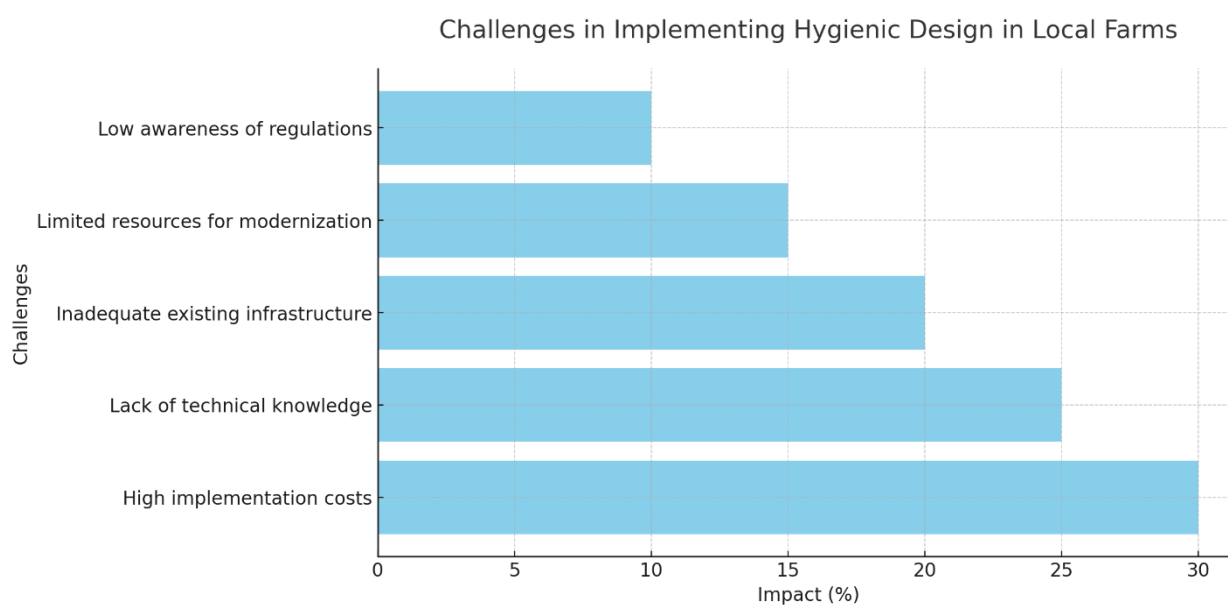
Impact:

- A 25% reduction in raw material losses due to efficient processing.
- An 18% increase in sales through access to premium markets.

Table 3. Performance Indicators for HD Implementation at Izvorul Muntelui Farm (Neamț County)

Performance Indicator	Before Implementation (2021)	After Implementation (2022)
Contamination Rate (%)	15%	9%
Product Validity Period (days)	5	8
Monthly Production Volume (litres)	3.000	3.800
Number of Customer Complaints	25	10

From discussions with farmers, Figures 2 and 3 illustrate the stages, benefits, and challenges of implementing hygienic design.

**Fig. 2.** *The necessary steps for the implementation of Hygienic Design and their impact***Fig. 3.** *The challenges of implementing hygienic design in mountain farms*

5. Results and Discussions

The implementation of Hygienic Design (HD) concepts has demonstrated a significant impact on food safety in mountain farms. The reduction of biological and chemical contamination risks, highlighted by lower contamination rates across all analyzed case studies, underscores the effectiveness of these measures. For instance, the Valea Lupului farm reported a 30% reduction in bacterial contamination, while the shelf life of dairy products increased by 20%.

Adopting HD also contributed to enhanced operational efficiency. Corrosion-resistant materials and smooth surfaces enabled fast and effective cleaning, reducing downtime. Moreover, infrastructure modernization facilitated an increase in production volume and a decrease in consumer complaints. The implementation costs posed a major barrier for most mountain farms. Investments required for modernizing infrastructure and purchasing equipment compliant with international standards are high, and access to funding is often limited.

The lack of technical training for staff was another significant challenge. The absence of accessible training courses and information about international standards resulted in incomplete implementation of food safety measures. The geographical conditions specific to mountain areas, such as poor infrastructure and limited accessibility, restricted the ability to deliver perishable products quickly and amplified contamination risks.

The results achieved by mountain farms in Romania are comparable to examples of best practices from other mountainous regions, such as Switzerland or Austria. For instance, European studies have shown that implementing Hygienic Design in small and isolated farms led to a 40% reduction in losses due to product contamination, similar to the reductions reported by the Țara Moșilor farm. International experiences suggest that cross-border partnerships and exchanges of best practices can accelerate the adoption of food safety technologies and standards in mountain areas.

6. Conclusions

The study highlights the importance of implementing Hygienic Design concepts in mountain farms to improve food safety. The case study results demonstrate significant economic, operational, and sanitary benefits:

- Reduction of biological and chemical contamination risks.
- Increased shelf life of food products.
- Streamlined operational processes through the use of equipment designed according to international standards.

The paper also emphasizes that, despite numerous challenges, the proposed solutions can transform mountain farms into models of best practices.

Practical Recommendations

For farmers:

- Gradually adopt Hygienic Design principles, focusing on modernizing storage and processing spaces.
- Participate in training courses on food safety and the application of good hygiene practices.

For authorities:

- Provide subsidies for investments in infrastructure and equipment.
- Organize awareness campaigns about the importance of food safety in mountain areas.
- Facilitate access to local and international markets by promoting mountain products.

Future Research Directions

- Extend research to include other types of farms, such as vineyards or fish farms in mountain areas.
- Develop customized guidelines tailored to the specific needs of each mountain region.
- Explore the potential of advanced technologies, such as artificial intelligence, for monitoring and optimizing food safety.

General Conclusion

Mountain farms are a valuable resource for local communities but also present a challenge in ensuring food safety. Implementing Hygienic Design concepts, combined with investments in education, modern technologies, and infrastructure, can transform these farms into examples of sustainability and quality. International partnerships and government support are crucial for the success of these initiatives.

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STUDY ON BIOHARMONIZATION OF THE FOOD SYSTEM THROUGH ANIMAL PROTEIN INTAKE

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Abstract: Starting from the premise of the transformation of cereals into meat, milk, eggs and other animal products and the optimized flow from farm to plate, as the desired and essential direction of the integrated food system of the civilized world, the work focuses on the optimization of agro-zootechnical anthroposystems through a series of conceptual contributions at the systemic level. With the idea of finding some application solutions with increased yield, the study proposes as its main objective the nuance of some directions of development of animal husbandry in the future based on multiple integration necessary to maximize the added value, supported by the bioharmonization process. Elements of the quality of animal proteins are addressed along the lines of applied biology and technical-economic direction applied at the level of zooproduktive system, highlighting the impact on the human body through the process of multiple integration with a tendency to bioharmonize the act of eating. At the same time, the scientific and technical optimization of the animal breeding system in relation to the environment and its resources, as well as the adaptation to the demands of society in profound change, is taken into analysis.

Keywords: bioharmonism, animal protein, integration, food system

1. Introduction

UN studies show that it is becoming urgent how we use natural resources along the entire axis "from farm to plate", along the lines of sustainability and resilience, that is, to optimize and maximize the yield and efficiency of the food chain, in the conditions of climate, social and geopolitical changes.

The quality of the food system is directly related to the production of animal protein found in the food act on the "farm to plate" axis. This in the sense that the human body can produce non-essential amino acids, while essential amino acids can only be obtained from food.

It should be noted that the superior added value in the supply of essential amino acids comes especially from ANIMAL PROTEINS (being complete, knowing that incomplete proteins are generally obtained from vegetable sources). It is also known that animal proteins are extremely important in the growth and harmonious development of children, adolescents and during pregnancy. The purpose and usefulness of the study: "AGRO-RURAL-URBAN" is the axis that actually celebrates the

richness and diversity of the food heritage, simultaneously highlighting the meaning of INTEGRATION in the act of food and related services. This through a series of benchmarks applicable in Romania as well, such as the bioeconomic harmonization of nutrition in terms of quantity and quality. More specifically, the mode and feeding circuits in large urban agglomerations, both in daily dynamics and as tourist destinations. The idea of optimizing the food system through multiple integration also refers to the principles and practices of animal husbandry, by managing resources to improve production efficiency, their health and the sustainability of production systems. It is a complex and multidimensional process aimed at optimizing animal production through the use of scientific knowledge and modern management techniques: genetic improvement, animal nutrition, health management, sustainability and integration throughout the food chain, based on the principles and methods of bioeconomic animal husbandry [12].

As objectives, the work aims to optimize and better understand the systemic aspects related to the dynamic balance of animal production

anthroposystems, in accordance with an Integrated Food Policy on the agro-rural-urban axis. Focused, the work aims to highlight the importance of nutrition based on quality animal products, thus contributing to solving the "hunger" of animal protein. This by reorienting the activity of zootechnical anthroposystems in the direction of quantitative balancing based on mechanisms and principles of bioharmonization with the qualitative intake of food, improving the act of eating. A better understanding of the systemic aspects related to the dynamic balance of animal production is emphasized, in correlation with the sanogenic impact on the body of consumers through the consumption of animal protein.

2. Methodology

The basic methodological concept is related to the strategic synthesis of the food act, with concrete elements regarding the analysis of the trend of development and integration of animal husbandry, using principles of multicriteria analysis, comparisons and statistical processing [9, 12, 24]. It calls for a managerial diagnosis with emphasis on the socio-economic aspects of the components of the integrated food system. Methodologically, the principles, techniques and directions specific to sustainable development regarding the provision of food of animal origin are also considered.

Structural and functional tabular and schematic expressions are made as a guide to action with applications in policies and strategies for quantitative and qualitative development of animal production and related food processing in contemporary decades.

As a method, the techniques and principles of the concept of bioharmonism are also used [14] within the integrated food system, necessary to improve the quality of food through a high proportion of **animal proteins**.

N.B. In this context, we recall the definition of the reference pillars: - BIOHARMONISM = notion

related to the systemic harmonization regarding balanced diversity and holistic organization in relation to the complex model of Nature and the existential triad (I, E, S), having as a benchmark the information of the "living" ("bio-") and the non-linear reality of life, in

its complexity and in convergence with the technical-economic and socio-cultural models of the current society. / - ANIMAL PROTEINS = substances that play a crucial role in human nutrition, contributing to general health and well-being due to their high nutritional value and bioavailability, being practically the complete source of essential amino acids [11, 15].

3. Results and discussions

An integrated food system refers to the holistic approach to food production, where various components of the agro-livestock system are interconnected to maximize efficiency, sustainability and quality of food products.

Here are some key aspects of this concept: sustainability, interconnectivity, diversification of production, food safety, innovation and technology, education and involvement of specialized human resources (farmers, processors, hoteliers, etc.) and various local actors.

We find that an integrated food system provides a comprehensive approach to food production that leverages synergies between the different elements of agriculture and animal husbandry to promote sustainability, efficiency and food safety, down to the consumer level [1, 3, 6, 18, 31, 33].

Livestock production in relation to the integrated food system is a concept that refers to a holistic and sustainable approach to food production and consumption, based on the integration of all stages of the supply chain, from agricultural production to final consumption. This may include interactions between different sectors such as agriculture, animal husbandry, food industry and trade (fig.1).

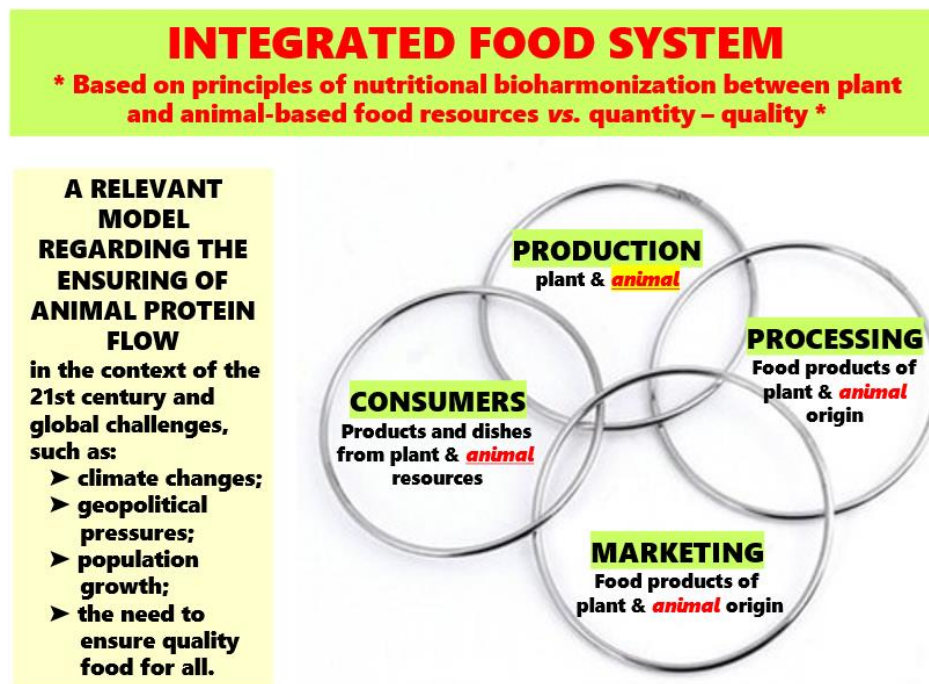


Fig. 1. Block diagram of the food system highlighting multiple integrations and the omnipresence of animal foods

The functionality of the integrated food system is based on a series of CHARACTERISTICS in integrative dynamics (multiple integration with synergistic and emergent effect) regarding the collaboration between subsystems (sectors) along the lines of sustainability, economic efficiency and social responsibility. The bioharmonization of all these characteristics is the necessary step to formulate the INTEGRATED FOOD POLICY. We are essentially referring to a coherent guide that has the power to ensure the population's access to a safe, healthy, diversified diet, of good quality and in sufficient quantity, produced in economically and socially acceptable conditions for all. At the same time, it is necessary for public policies to favor employment, protect the environment and landscapes and contribute to mitigating and adapting to the effects of climate change [5, 19, 20, 28]. The integrated food policy provides for the renewal of legislation and various regulations in order to permanently adapt the system to the parameters necessary to be in dynamic balance, i.e. to be optimized, integrated, coherent and ethical [33].

The maximization of systemic effectiveness has in mind the design of zooproductive ecosystems or zootechnical anthroposystems based on well-defined holistic models, WITH DIFFERENTIAL DEGREES OF ANTHROPIZATION, models made principally on 3 complementary directions

of action, namely: ensuring quantity, raising quality and capitalizing on biodiversity.

3.1. Analysis of the Food System on the Line of Ensuring the Quantity of Food through Animal Products

It can be seen that animal production systems with animal products in QUANTITIES necessary and sufficient for the demographic explosion are currently obtained mainly through intensive-industrial systems. They have high economic efficiency, but low systemic effectiveness, production is carried out on a "metabolic" direction (reproduction, growth and development of the animal body, utilization of production). As variants, production can also be done through systems and strategies of modular agro-zootechnics (in a controlled environment and space) and including cellular agriculture principles (starting from STEM cells).

The food from animal production obtained according to the principle of quantity has in mind the provision of food for large urban agglomerations, which is why in the last decades agro-zootechnics has developed on an intensive-industrial system, located mainly in the peri-urban area. Intensive zootechnical anthroposystems (production 3-6 times compared to traditional systems) and industrial systems are found (quantitative production is increasing

rapidly, ensuring quantities of animal products that cover the requirements of large urban agglomerations). We specify that systemically they are inverse biotope pyramids profiled on obtaining animal products from a single species raised in absolutely controlled conditions (complexes of birds, pigs, cattle) with high energy consumption and major impact on the environment and with considerable pollution of

the environment. This contributes, along with other pollution factors (industry, transport, etc.) to the disturbances that have led to unprecedented climate changes [2, 7, 30]. The block diagram of the classic food circuit of animal products "from farm to plate" that we developed in the sense of those analyzed previously, is reproduced in figure 2.

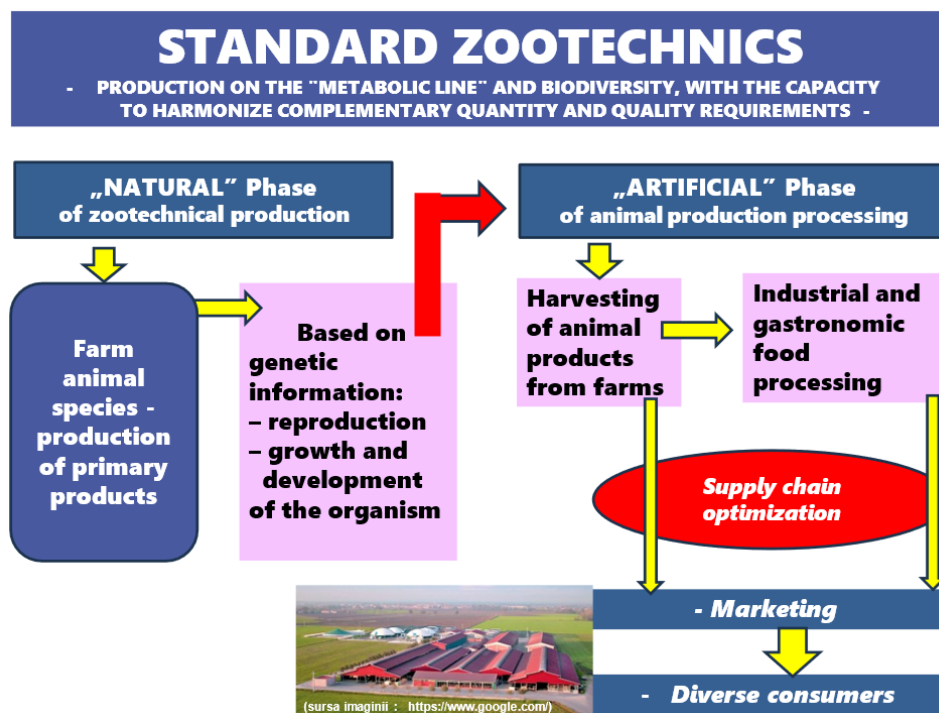


Fig. 2. Block diagram of obtaining animal products in the classical system

The possibility of ensuring sufficient quantities of animal products and functioning towards food security is shown, but the huge problem of standard animal husbandry is related to pollution and climate changes, to high energy consumption, to the limiting factors regarding forage (the reduction of the surfaces in the agro-pastoral area), of the increasing demands related to the demographic evolution, all justifying studies to find alternative solutions.

3.1.1. Quantitative Production of Animal Products by Alternative Methods

The time has come to move, with optimism, from the classical probabilistic animal husbandry to the alternative animal husbandry of very high economic efficiency and systemic effectiveness. Current science offers unsuspected possibilities and applicability in the field of the food system along the lines of production and consumption of food of animal origin and high-quality protein intake [7, 8, 12, 16, 17].

An example is the in-depth molecular and cellular approach carried out with state-of-the-art equipment, using all kinds of sensors, which measure a multitude of effects that take place inside and outside the animal's body in the special environment (of the animal shelter), as well as integrated algorithms, the use of AI through robots that will be developed in the next period. The most diverse activities of people in livestock farms are almost completely replaced. Simultaneously with the technical and biological-informational aspects, the new approach extends to the systemic level along bioeconomic lines, so that the complete picture of expression of alternative animal husbandry can be generated, in which an important direction is the production of "binary foods" (cumulative elements natural & artificial) [13, 15, 27], as shown in figure 3.

The advantage of animal production in alternative systems is that it is possible to obtain the necessary quantities of products of animal origin, i.e. solving the hunger for animal protein

by reducing the dependence on conventional energies and increasing the ecological yield for

the significant decrease in environmental pollution.

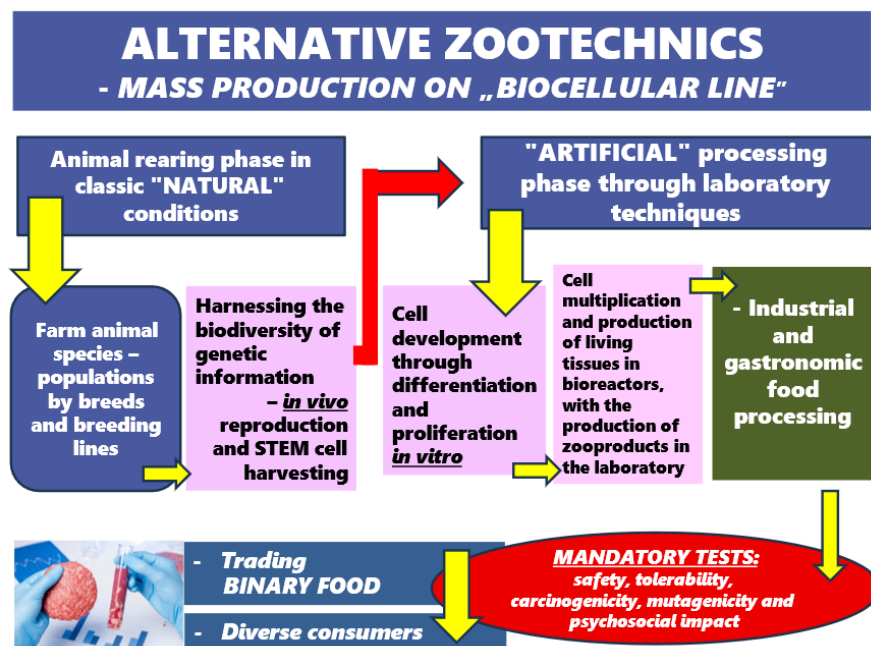


Fig. 3. Block diagram of obtaining animal products in an alternative system based on the principles of cellular agriculture

This taking into account the integration of production in balanced trophic chains of the food act, recycling, self-regulation, new technologies and environmentally friendly materials, as well as a creative management of the integrated food system. Essential in the new paradigm is the balanced and unprejudiced approach to the societal need for all types of food, i.e. to induce a constructive mentality of complementarity and NOT destructive exclusion (linked to obscurantism and mercantile interests).

The argument being that the unknown prospects of the future impose the idea that humanity must face all the challenges of providing food of animal origin in the conditions of major climate changes, those of a geo-political nature, but also in the prospective scenario of space colonization [4, 8, 10, 21, 22 - 26, 29, 32].

The concept and process often exemplified is that of "cultured meat" which is basically a technology that can solve the problem of animal protein hunger, but also the "humanization" of the production system by avoiding the breeding and technological killing of animals, avoiding pollution and the droppings of the large zootechnical complexes, as well as the work of great difficulty and in some aspects considered to be degrading. In the new paradigm, food of animal origin is usually made in two complementary phases: the "natural" phase and the "artificial" phase, both having different weights regarding human intervention, depending on the technological model. Therefore, conceptually and semantically, we refer to two distinct notions, namely: "natural foods" (classical) and "binary foods" (developing), as shown in Table 1.

Table 1. The typology of food according to the cumulative contribution of the natural environment and of man in the production processes

PRODUCTION STAGE	NATURAL FOODS (with reduced human intervention, the predominant role being the contribution of the environment, so systems by natural "metabolic" path)	BINARY FOOD (with intake based on natural genetic information specific to living animals, but with human intervention in processing, through artificial cell multiplication)
In the "natural" phases:	• Primary products: These are the products that are obtained directly from nature, without significant human intervention, or with minimal interventions. For example, agricultural harvest (grains, fruits, vegetables), milk, honey, forest resources or fishing.	- Harvesting Embryonic stem cells – they have a very high capacity to transform into any type of cell; - Harvesting Adult stem cells – taken from muscle, with the ability to transform into only

	• Organic/bio products: These are products resulting from methods of cultivation and growth that aim for a minimum of chemical or technological intervention, so as to preserve as much as possible the natural characteristics (bioactive components).	certain types of cells (such as muscle or fat cells).
In the "artificial" phases:	Obtaining first processing products: - for example, those that are obtained by transforming natural products through various technological processes of food hardening, such as flour, oil, sugar, etc.	Obtaining animal tissues : - example muscle tissue made by a process that, through inherited genetic information, mimics the natural development of muscles in a living animal such as steak, etc. Obtaining composite foods : - example food from the food industry Obtaining complex foods : - for example culinary preparations from the gastro industry.

3.2. Analysis of the Food System on the Line of Food Quality Assurance through Animal Products

Regarding obtaining high-QUALITY animal products, the systems offered by eco-farms are of reference (example: polyculture, permaculture, extensive natural, traditional and/or mountain livestock systems, regenerative, biodynamic systems, etc.).

High-quality animal products are known to be foods from farms and animal husbandry systems that prioritize nutritional quality, taste, safety and sustainability [3, 6, 12]. These products, which include meat, milk, eggs, etc., including various by-products, necessarily comply with rigorous standards in terms of composition, purity and methods of obtaining (table 2).

Table 2. A synthesis of the characteristics of high quality animal products

No. crt.	QUALITY INDICATOR	BRIEF ANALYSIS
1.	Superior Nutritional Value: the presence of animal protein and bioactive substances	• High-quality animal products have a rich nutritional profile, containing high-quality protein, vitamins (such as vitamins B and D), minerals (calcium, iron) and essential fatty acids. For example, milk from organically raised or pasture-fed cows may be higher in omega-3 fatty acids.
2.	Superior Taste and Texture:	• The taste of these products is often more pronounced and complex due to the natural growing conditions and specific feeding of the animals, which contribute to the development of unique flavors and textures.
3.	Controlled Origin and Traceability	• High-quality products are usually labeled in such a way as to allow consumers to know their origin, the conditions in which the animals are raised and fed, the processing methods and any treatments given to them.
4.	Sustainability and Animal Welfare	• Farms that produce high-quality animal-based foods tend to adopt sustainable practices, such as reducing environmental impact and providing better living conditions for animals. This includes access to open spaces, natural food (via grazing) and avoiding animal stress.
5.	Food Safety	• These products meet strict safety standards, avoiding harmful chemicals (pesticides, antibiotics or growth hormones) and reducing the risk of bacterial contamination through strict hygiene processes.

3.2.1. Achieving the Quantitative and Qualitative Need for Animal Protein through the Valorization of Biodiversity

A third direction in the evolution of the food system, a direction that is currently on the rise, is the DIVERSIFICATION of production along the lines of valorizing biodiversity and introducing new types of foods of animal origin and therefore a greater protein supply. Therefore, animal products are a consistent and varied source of

HIGH-QUALITY PROTEIN, and their moderate inclusion in the daily menu can support muscle health and development, immune function and metabolism [12, 15]. Thus, the protein content of animal products is an important factor in human nutrition, because these foods are major sources of complete proteins, which contain all the essential amino acids needed by the body (table 3).

Table 3. *The quality of the food act by ensuring complete proteins from the biodiversity of animal species*

No. crt.	GROUP OF ANIMAL PRODUCTS	BRIEF CHARACTERIZATION REGARDING THE NUTRIENT INTAKE IN FOOD
1.	Meat products	➤ Meat (beef, pork, chicken) generally contains between 20-30% protein. It is an essential source of high-quality protein, B vitamins, zinc and iron.
		➤ The type of meat and method of preparation can influence the protein content, with lean meat (skinless chicken or turkey) having a higher percentage of protein per gram compared to fattier meat.
2.	Milk products	➤ Milk, cheese and yogurt provide between 3-10% protein, depending on the type of product and fat content. Skimmed milk products contain more protein per gram compared to full-fat.
		➤ Ripened cheeses, such as Parmesan or Cheddar, have a higher protein content (up to 30%) and provide calcium, phosphorus and vitamins B2 and B12
3.	Fish and seafood	➤ Fish and seafood are high in protein (about 20-25%) and provide heart-healthy Omega-3 fatty acids.
		➤ Species such as salmon, tuna and sardines are also important sources of vitamins and minerals.
4.	Eggs	➤ Eggs are among the most complete sources of protein and contain all nine essential amino acids. A medium egg contains about 6 grams of protein, split between the white (which contains most) and the yolk.
		➤ In addition to protein, eggs provide vitamins D, B12, and choline, essential for neurological function and brain health.
5.	Products of insect origin	➤ <i>Bee products</i> used both in food and in medicine, due to their nutritional and therapeutic properties, and among the most recognized in human nutrition are: Honey / Pollen / Propolis / Royal jelly.
		➤ " <i>Entomophagous</i> " products refer to food products produced by or derived from insects and consumed by humans. These products are part of the process of entomophagy, that is, the practice of consuming insects as a food source. Insects are increasingly recognized for their nutritional value (rich in protein, vitamins, minerals and healthy fats), as well as their sustainability and environmental benefits. / Entomophagy products may include: whole insects, insect meal, insect protein bars and snacks, insect oils, insect supplements, insect sauces and condiments, etc.
		➤ <i>Non-food sericulture products</i> come from the rearing of silkworms (especially <i>Bombyx mori</i>), which are used to produce silk, but in the context of food, there are also products that can be consumed: silkworm larvae, being rich in nutrients, are consumed as a source of protein, particularly in certain Asian countries, silkworms are considered a delicacy.

In gastronomy, animal products are a consistent and varied source of high-quality protein, and their moderate inclusion in recipes, menus and diets can support brain health and muscle development, immune function and metabolism. Authentic high quality has a deep connection with the source of the food, traditional cooking methods and respect for the ingredients used.

It's basically about "feeling" and appreciating every detail of the food as it has been cooked for centuries. The effect is maximized if food ingredients produced on the basis of ecological and biological technologies are used [2, 7, 21], with a brief example of the groups of organic animal products (table 4).

Table 4. *Examples of organic livestock products with fortified quality*

FOOD GROUP	QUALITY THROUGH ADDED VALUE	ORGANIC IMPACT AND HEALTH SUPPORT
MEAT	<i>High quality beef</i>	➤ such as that from grass-fed animals (e.g.: mountain pastures) is valued for its healthy fat profile (unsaturated fatty acids) and a more authentic taste (pure, unadulterated flavor with a high natural and traditional weight).
DAIRY	<i>Organic dairy products</i>	➤ they contain less antibiotic and pesticide residues, having a better nutritional value (validation by parameters).
EGGS	<i>Eggs from free-range chickens</i>	➤ they have a higher content of vitamins, such as vitamin E and D, and a balanced fat composition.

The added value in the integrated food system also has a dimension directly related to the CONSUMER, respectively on the processing line through modern food technologies and through the gastro industry of excellence. In this sense, the bioharmonization of the food system requires the integration of high-quality animal products, in relation to the growing demands of consumers who want not only a nutritious and/or healthy food, but also a reduced impact on the environment and increased respect for animal welfare.

Conclusions

1. The design of zooproductive ecosystems or zootechnical anthroposystems based on well-defined holistic models, WITH DIFFERENTIAL DEGREES OF ANTHROPIZATION, can maximize systemic effectiveness by principally addressing three directions of action, namely: ensuring quantity, raising quality and capitalizing on biodiversity. All these are in fact benchmarks that form the basis of the formulation of the INTEGRATED FOOD POLICY, as a coherent and dynamic guide for continuous adaptation to current societal changes.

2. Animal production in relation to the integrated food system is a holistic and sustainable approach to food production and consumption, based on the integration of all the stages of the well-known axis "from farm to plate", expressed methodologically through the process of bioharmonization, having as a benchmark the valorization of animal protein.

3. The gradual transition from the classic probabilistic animal husbandry to the alternative animal husbandry of very high economic efficiency and systemic effectiveness requires the technological reorientation of the intensive-industrial systems of the present, having high economic efficiency, but low systemic effectiveness, operating on a classic model of production by direction "metabolic" (reproduction, growth and development of the animal organism, production valorization), transition supported by new systems and strategies developed on bioeconomic principles of modular agro-zootechnics (in a controlled environment and space), or cellular agriculture (starting from STEM cells, with well-specified

methodologies and framed in ethical codes), with obtaining binary food.

4. An emerging direction in the development of the integrated food system is the DIVERSIFICATION of production along the lines of valorizing biodiversity and introducing into the food act new types of food of animal origin from species that, beyond current prejudices, can be useful in feeding from a biological and economic perspective, thus increasing the supply of complete proteins (rodent species, batrachians, seafood, or "entomophagous" products which refer to the products beekeeping, silkworms, insect consumption, etc.).

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THE APPLICATION OF RESPONSE SURFACE METHODOLOGY FOR DEVELOPMENT OF SENSORY ACCEPTABLE WALNUT CHEESE-LIKE ALTERNATIVES

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Abstract: Response surface methodology (RSM) is one of the most important multivariate techniques extensively used in recent years to model and optimize formulations and processing conditions in food technology. In this study, RSM was used to develop sensory acceptable, walnut cheese-like alternative to satisfy consumers who want to avoid animal products and to offer new options for vegetarians and health-conscious consumers, improving the range and quality of plant-based diet choices. The experimental design assessed the effects of three independent variables: walnuts/water ratio (1/13.3 – 1/2.56), walnut oil content (11.6 – 18.4%) and instant yeast amount (1.2 – 2.8%). Measured responses included appearance, color, flavor, taste, consistency and overall sensory acceptability (OSA) of all walnut cheese-like alternative formulations. The primary factor affecting ($P < 0.05$) all the responses was the walnut/water ratio used for walnut cheese-like alternatives production.

With respect to reference sample, higher ratio of walnut/water revealed better taste and contributed to more pronounced nutty flavor of the product. The soft, creamy/smooth attributes and creamy appearance represented all formulations and were related to consistency and appearance, indicative of quality in product formulations.

Keywords: consumer acceptance, sensory study, walnuts, plant-based cheese alternatives.

1. Introduction

Augmented interest in plant-based foods has increased due to concerns related to health, sustainability, and animal welfare. In terms of conventional production of dairy, there are three major areas of concern: environment impact, human health, and animal welfare [1, 2].

Therefore, plant-based products offer a more sustainable and ethical option to consumers that are rapidly increasing in popularity among consumers. As a testament to this, U.S. retail sales of plant-based substitutes that directly replace animal products grew 29% between 2017 and 2019 to reach a USD 5 billion market. In the dairy category plant-based cheese substitutes (PBCS) saw the most growth in a year-over-year

retail sales comparison by increasing 95% in 2020 [3, 4].

At the same time, approximately 46% of European consumers are reducing their animal food consumption, and 39% intend to reduce it in the future. Even though only a small proportion (approximately 7%) of Europeans are eating fully or mostly plant-based, the number of Europeans following a flexitarian diet (approximately 20–30%) is rising, with the largest share in the Netherlands (42%) and Romania (40%) [5].

Consumer liking is arguably the biggest challenge for any plant-based substitute. From a US consumer standpoint, only 32% agree that PBCS taste as good as regular cheese, while 34% disagree, and another third of cheese consumers remain indifferent [3, 6]. If the PBCS express

quality attributes that meet consumers' expectations, then these substitutes can be a satisfactory replacement for a dairy counterpart [7, 8].

The Food and Health Survey consistently shows that taste is the number one driver behind purchase intention [9, 10], more important than price, convenience, and health.

Therefore, it is important to develop a product that provides desirable sensory characteristics (i.e., taste, flavor, and mouthfeel properties) [11, 12, 13].

In summary, the low sales margins indicate that the consumer market is left unsatisfied and there

is substantial room for improvement and growth within this product category.

The aim of the study was to use Response Surface Methodology (RSM) to develop sensory acceptable, plant-based cheese-like alternative using different combinations of walnut milk, walnut oil and instant yeast.

2. Materials and methods

Walnut milk preparation was carried out essentially following the procedure presented in Fig. 1 [14].

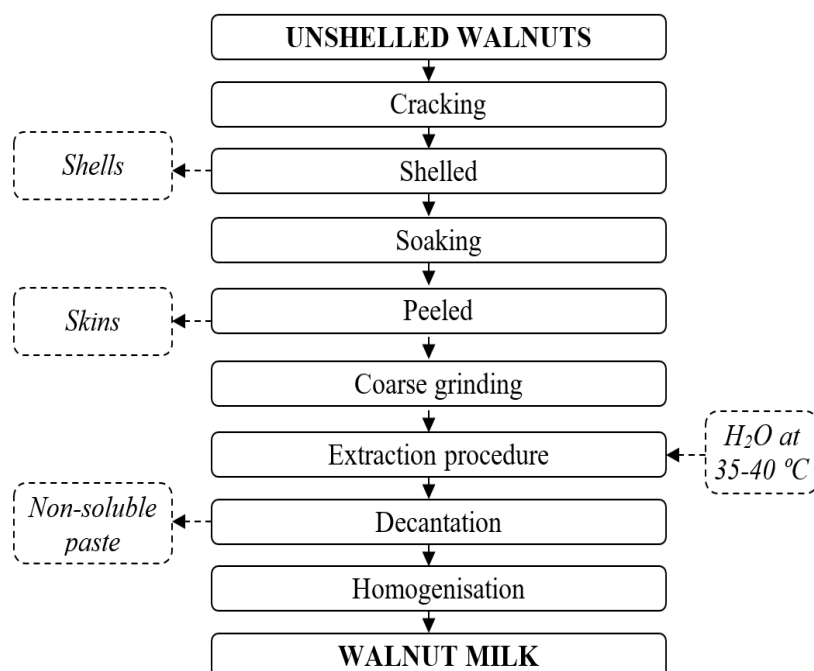


Fig. 1. Walnut milk processing flow diagram

Walnut cheese-like alternative formulations were prepared as follow: all ingredients are weighed, combined and mixed in a blender bowl for 3 minutes until a homogeneous composition was formed. After that, prepared composition was boiled for 5 minutes until it became thicker. After the heat treatment, all formulations were placed in lidded storage containers (polycarbonate) and were kept at +4 °C for further sensory evaluation [15].

The optimization of the walnut cheese-like formulations was carried out in the STAT-EASE 360 program in order to compare how the sensory attributes of the walnut cheese-like alternatives are influenced by application of

different concentrations of walnut milk, amounts of instant yeast and walnut oil. As a result, 20 walnut cheese-like formulations were prepared using different combinations of independent variables, applied in this study [16]. The 21st formulation was a reference one based on cow milk (Table 1).

Students and professors of the Faculty of Food Technology, Technical University of Moldova were involved in sensory evaluation of walnut cheese-like alternative formulations using a 5-point hedonic scale. Each formulation was labelled with a number (Fig. 2).

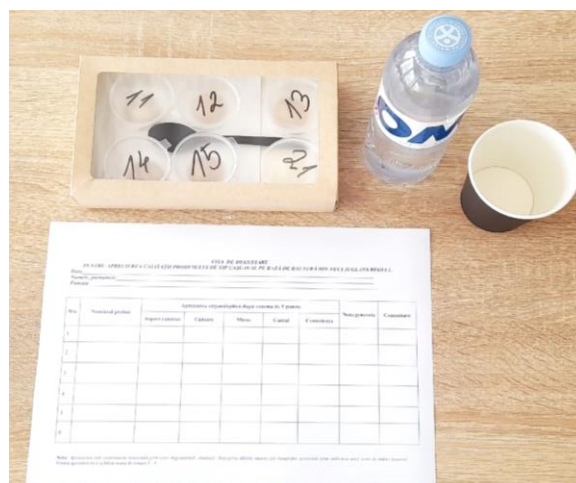


Fig. 2. Panelists table for sensory evaluation of walnut cheese-like formulations

The tested attributes included: *appearance* (1=extremely dislike, 5=extremely like); *color* (1=extremely dislike, 5=extremely like); *flavor* (1= imperceptible, 5=extremely pronounced); *taste* (1=extremely imperceptible, 5=extremely pronounced); *consistency* (1=extremely dislike, 5=extremely like,); and *overall sensory acceptability* (1=extremely dislike, 5=extremely like).

To represent the fitted response value, the linear, special cubic, and special quartic models were used. To make predictions about the response for given levels of each independent variable, the equations were used in terms of coded factors. The statistical significance of each

equation was determined by variance analysis (ANOVA).

3. Results and discussions

Sensory study included tasting of walnut cheese-like formulations by panelists and evaluating the main sensory attributes of the product. Based on individual tasting sheets, an average score was calculated for all evaluated sensory attributes: appearance, color, flavor, taste, consistency and overall sensory acceptability (OSA), presented in Table 1.

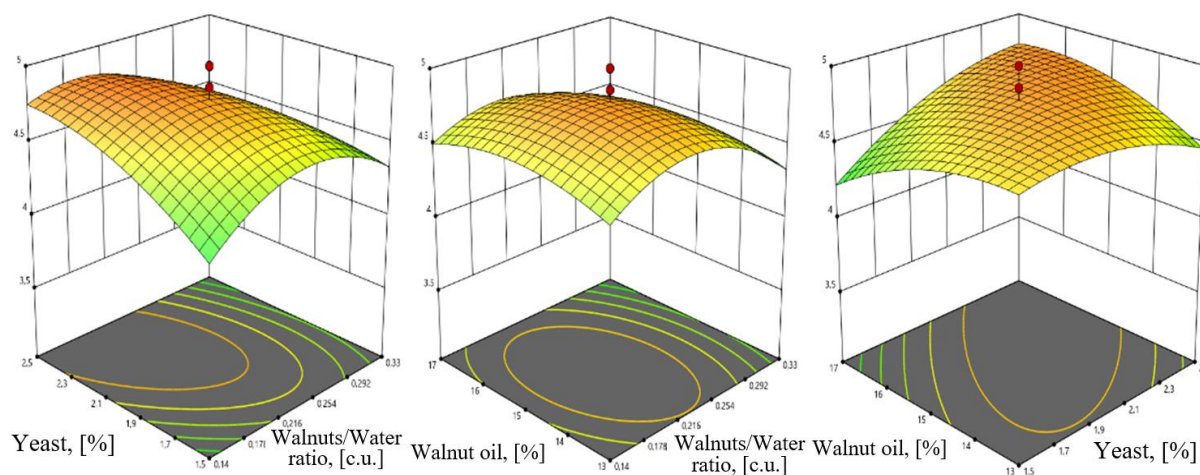
The interaction effect of the process parameters was studied using response surface plots, which helped predict the optimal levels of each parameter to achieve maximum sensory values.

Table 1. Effects of different walnut cheese-like formulations on the sensory attributes

Formulation	Independent factors			Response variables					
	Walnut/ water ratio, [c.u.]	Walnut oil, [%]	Instant yeast, [%]	Appearance	Color	Flavor	Taste	Consistency	OSA
1	0.24	15.0	2.0	4.86±0.18	4.71±0.19	5.0±0.11	4.14±0.07	4.57±0.19	4.66±0.19
2	0.24	15.0	2.0	4.86±0.18	4.71±0.19	4.71±0.19	4.29±0.15	4.57±0.19	4.63±0.12
3	0.14	17.0	2.5	5.00±0.11	4.71±0.19	4.14±1.17	4.29±0.19	4.71±0.19	4.57±0.19
4	0.24	15.0	2.0	4.71±0.19	4.71±0.16	4.57±0.13	4.43±0.13	4.57±0.13	4.60±0.18
5	0.24	15.0	2.0	5.00±0.21	4.85±0.11	4.86±0.18	4.14±0.10	4.71±0.16	4.74±0.18
6	0.24	15.0	2.8	4.25±0.11	4.25±0.18	3.75±0.16	3.42±0.12	3.92±0.16	3.92±0.12
7	0.33	17.0	2.5	4.42±0.16	4.42±0.16	3.67±0.12	3.75±0.18	3.75±0.16	4.00±0.19
8	0.24	18.4	2.0	4.25±0.11	4.42±0.16	3.85±0.15	3.92±0.12	3.58±0.10	4.00±0.17
9	0.33	13.0	1.5	4.25±0.16	4.42±0.11	4.00±0.18	4.00±0.17	3.75±0.19	4.08±0.17
10	0.24	15.0	2.0	4.25±0.11	4.42±0.16	4.08±0.10	3.75±0.15	4.08±0.12	4.12±0.10
11	0.39	15.0	2.0	4.20±0.14	4.60±0.15	4.00±0.11	3.20±0.12	4.20±0.12	4.04±0.17
12	0.14	13.0	2.5	4.83±0.11	4.83±0.11	3.80±0.10	3.60±0.18	4.33±0.12	4.34±0.14
13	0.24	15.0	2.0	5.00±0.11	4.83±0.11	4.00±0.19	3.80±0.14	4.50±0.15	4.46±0.16
14	0.24	11.6	2.0	4.67±0.12	4.83±0.11	4.00±0.19	4.33±0.12	4.83±0.11	4.53±0.12
15	0.24	15.0	1.2	4.67±0.12	4.67±0.12	4.33±0.12	4.00±0.19	4.50±0.15	4.43±0.16
16	0.33	17.0	1.5	3.50±0.15	3.83±0.15	4.00±0.19	3.67±0.12	3.33±0.12	3.67±0.19
17	0.14	13.0	1.5	4.00±0.19	3.83±0.15	3.67±0.12	3.83±0.15	3.67±0.12	3.80±0.10
18	0.07	15.0	2.0	3.83±0.15	3.67±0.12	4.00±0.19	4.00±0.19	4.00±0.19	3.90±0.12
19	0.14	17.0	1.5	4.17±0.18	4.00±0.19	3.83±0.15	4.17±0.15	4.33±0.12	4.10±0.19
20	0.33	13.0	2.5	3.67±0.14	4.00±0.12	3.67±0.15	4.00±0.12	3.83±0.10	3.83±0.15
21	-	-	-	3.70±0.18	4.02±0.12	3.88±0.15	3.64±0.16	3.58±0.17	3.76±0.16

Figure 3 shows the influence of three parameters on sensory evaluation. It was found that the lowest and highest ratio of walnuts/water used for walnut milk preparation has decreased in appearance values. The same correlation was

attested for the walnut oil amount used for walnut cheese-like alternatives preparation. However, higher content of instant yeast provided maximum appearance values of the product.

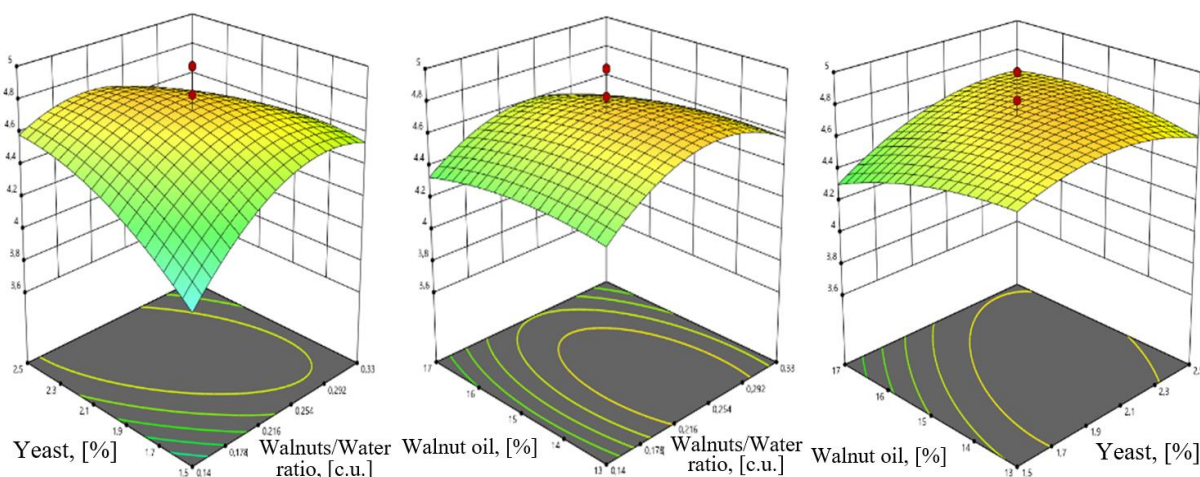


$$Appearance = 4.78 - 0.1126 \cdot A + 0.0947 \cdot B - 0.0268 \cdot C - 0.1650 \cdot A \cdot B - 0.0425 \cdot A \cdot C + 0.1875 \cdot B \cdot C - 0.2817 \cdot A^2 - 0.1244 \cdot B^2 - 0.1244 \cdot C^2$$

Fig. 3. Effect of independent variables on appearance attribute within sensory evaluation of the walnut cheese-like alternatives

It was noticed, that the application of instant yeast improved the color of walnut cheese-like formulations (Fig. 4). Incorporation of this ingredient into walnut cheese-like formulation increased the product range, as well as consumers' liking of the product. Figure 4 shows

that the color ranged from 3.67 ± 0.12 to 4.85 ± 0.11 . According to Table 1, formulations 5, 12-14, 16 and 17 showed higher color values in the formulations with a higher quantity of instant yeast and increased walnuts/water ratio.

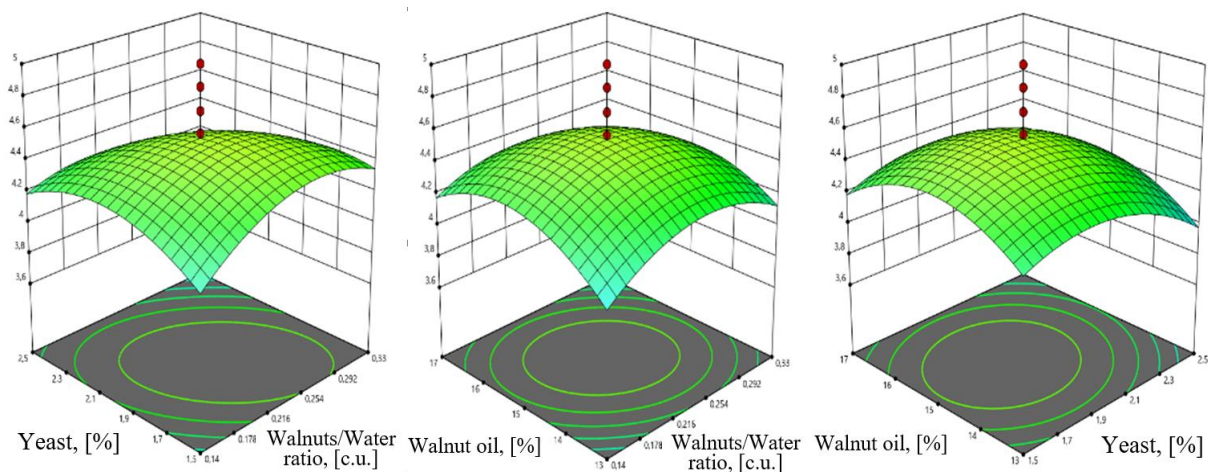


$$Color = 4.73 + 0.0633 \cdot A + 0.0859 \cdot B - 0.0593 \cdot C - 0.1925 \cdot A \cdot B - 0.0275 \cdot A \cdot C + 0.09 \cdot B \cdot C - 0.2382 \cdot A^2 - 0.1233 \cdot B^2 - 0.0650 \cdot C^2$$

Fig. 4. Effect of independent variables on color attribute within sensory evaluation of the walnut cheese-like alternatives

In figure 5, the response variable for flavor attributes has a good correlation with increased walnuts/water ratio and with walnut oil content of

15% and instant yeast of 2.0%. This can be explained by more pronounced nutty flavor of the product formulations.

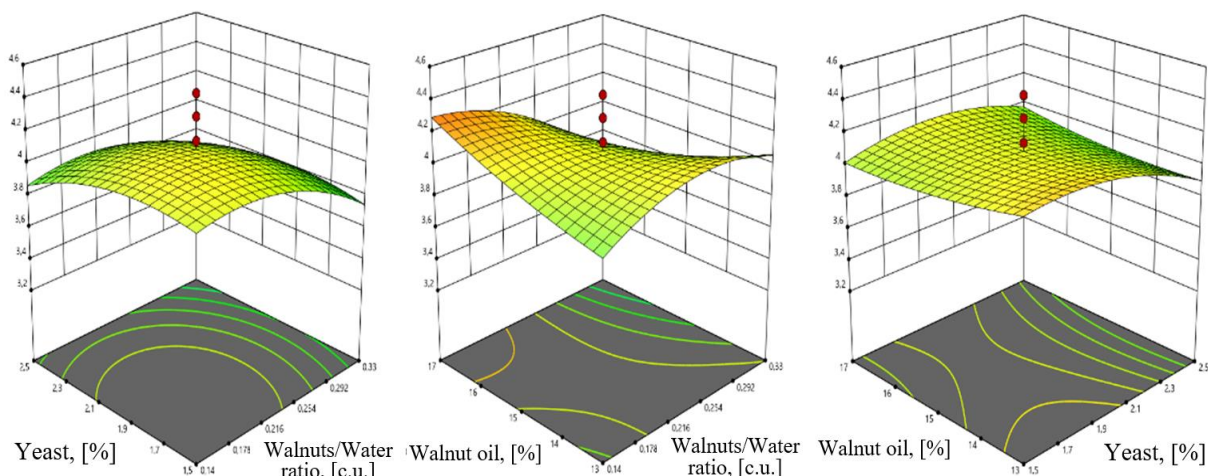


$$\text{Flavor} = 4.54 - 0.0073 \cdot A - 0.0875 \cdot B - 0.0181 \cdot C - 0.1375 \cdot A \cdot B - 0.0625 \cdot A \cdot C + 0.0225 \cdot B \cdot C - 0.2124 \cdot A^2 - 0.1983 \cdot B^2 - 0.2390 \cdot C^2$$

Fig. 5. Effect of independent variables on flavor attribute within sensory evaluation of the walnut cheese-like alternatives

The yellow and orange area of Figure 6 represents the highest taste values of the walnut cheese-like formulations and the corresponding combination of the independent factors required to achieve this level of taste. The results showed

that the best combination of the variables to maximize taste was to increase walnut oil content till 15%, instant yeast till 2.0% and to use walnuts/water ratio of 0.24.



$$\text{Taste} = 4.09 - 0.1329 \cdot A - 0.0736 \cdot B - 0.0175 \cdot C + 0.0238 \cdot A \cdot B - 0.2012 \cdot A \cdot C + 0.0538 \cdot B \cdot C - 0.1487 \cdot A^2 - 0.1098 \cdot B^2 + 0.0369 \cdot C^2$$

Fig. 6. Effect of independent variables on taste attribute within sensory evaluation of the walnut cheese-like alternatives

The yellow area of Figure 7 represents the highest consistency values and the corresponding combination of the independent factors required to achieve this level of consistency. The results showed that the best combination of the variables to maximize consistency was incorporation of

instant yeast of 2.5% and walnuts/water ratio of 0.24. The results showed that different amounts of walnut oil influenced insignificantly on consistency of the walnut cheese-like formulations.

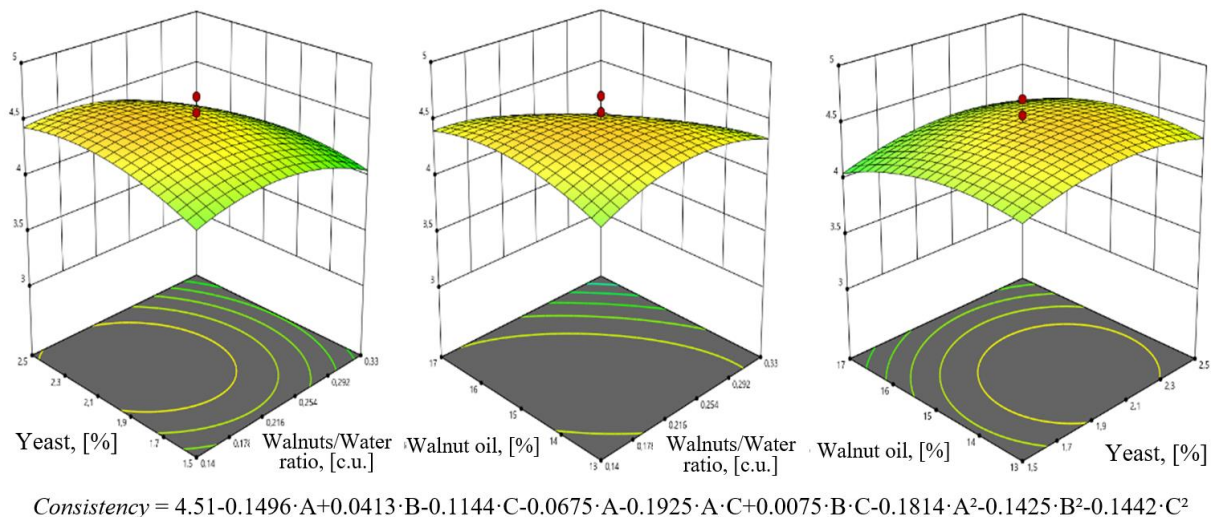


Fig. 7. Effect of independent variables on consistency attribute within sensory evaluation of the walnut cheese-like alternatives

The orange area of Figure 8 represents the highest liking of OSA and the corresponding combination of the independent factors required to achieve this level of OSA. The results showed that the best combination of the variables to

maximize OSA was walnuts/water ratio in the range between 0.24-0.3, content of walnut oil between 14-16 % and instant yeast in the range of 1.9-2.2%.

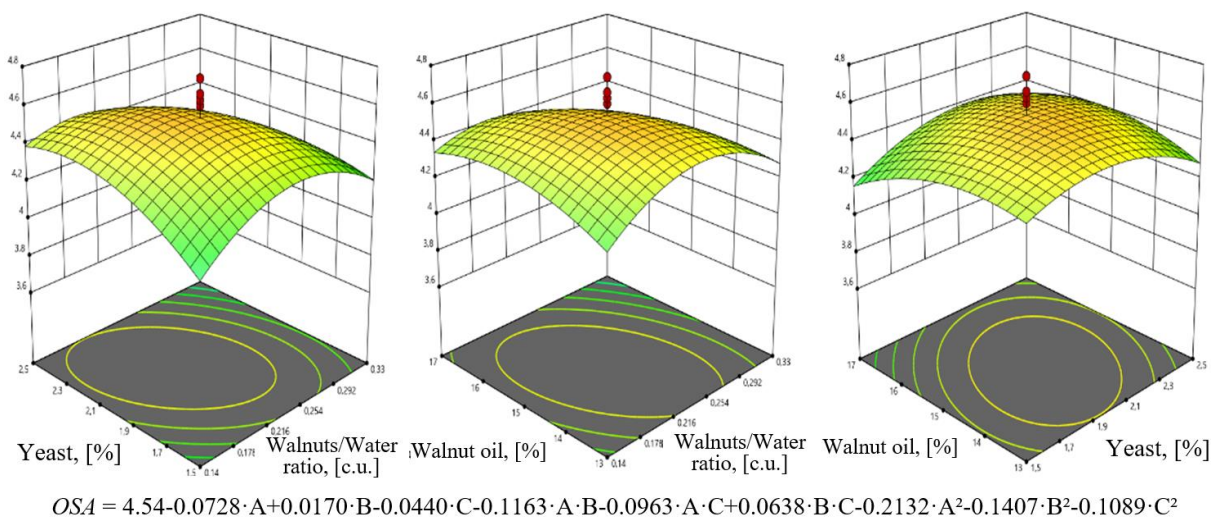


Fig. 8. Effect of independent variables on overall sensory acceptability (OSA) attribute within sensory evaluation of the walnut cheese-like alternatives

It is well known that sensory properties of food products are the most important attributes as they are the most apparent to consumers [17-20].

While attributes such as flavour, taste or consistency were predicted by the models, a higher ratio of walnuts/water used for walnut milk preparation was achieved when product optimisation was carried out based on OSA which subsequently produced a product with lower walnut oil content and increased instant yeast content; therefore, production of the

optimised walnut cheese-like formulation was carried out based on maximizing the OSA.

4. Conclusions

The results showed the effectiveness of the RSM application to develop sensory acceptable, plant-based cheese-like alternative based on walnut milk. According to the experimental results and three-dimensional response surface plots, an increase in walnuts/water ratio, used for

walnut milk preparation improved the taste and flavour of the product. The samples with higher contents of walnut oil received low sensory values.

This indicates that walnut oil has to be used in average amounts with instant yeast to ensure optimum consistency properties. The walnut cheese-like alternative with an optimized composition was found to have high sensorial acceptance.

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SUSTAINABLE VEGETABLE FARMING IN MOUNTAIN REGIONS: CHALLENGES, INNOVATIONS, AND ECONOMIC OPPORTUNITIES

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Abstract: This paper explores the specific challenges and opportunities of vegetable farming in mountainous regions, focusing on climatic conditions, soil characteristics, and crop selection. The analysis reveals how short growing seasons and difficult terrain require adaptive farming techniques, while the nutrient-rich and antioxidant-laden produce offers significant market potential. Detailed productivity comparisons between lowland and mountain farming are included, such as the lower yield of 15-20 tons/ha for potatoes in mountain areas compared to 30-40 tons/ha in lowlands. Specific water requirements are also analyzed, for instance, 180 m³/month for potato irrigation in April-May. Practical recommendations are proposed for optimizing production, including crop diversification, organic farming practices, and leveraging tourism opportunities

Keywords: mountain farms, renewable resources, sustainability.

1. Introduction

Upland vegetable farms are influenced by the specific conditions of altitude, soil and climate, having both unique advantages and challenges [20]. At altitudes above 500 m, temperatures are lower and the growing season is shorter, but solar radiation is more intense, which favors a higher quality of vegetables. Precipitation is more abundant but often unevenly distributed, and low nighttime temperatures slow plant growth but stimulate the production of secondary compounds with nutritional benefits. Mountain soils are rich in organic matter but have low fertility and shallow depth, requiring careful management [4, 5]. The risk of erosion is high, but terrace cultivation helps prevent it. Farms in these areas are often small and oriented towards organic, sustainable agriculture, being attractive to local markets due to their natural isolation from pollution [1, 6].

Not all crops adapt to harsh mountain conditions, but certain vegetables thrive due to their natural hardiness and short growing cycles. Cold-hardy vegetables include potatoes, cabbage (including kale), carrots and beetroot. They adapt well to mountain soils and provide nutrient-rich crops. Short cycle vegetables such as radishes, lettuce and spinach are ideal for short growing seasons, being grown in succession. Onions, garlic and dwarf beans are other viable options, and herbs such as thyme, rosemary and mint add

economic value, being hardy and prized for their therapeutic properties [7-9].

Mountain vegetables are special due to the high concentration of antioxidants such as polyphenols, flavonoids and carotenoids, compounds produced by plants in response to environmental stress conditions. These compounds improve the taste and nutritional value of vegetables, making them healthier and more attractive to consumers. Mountain farms stand out for the superior quality of their vegetables, due to the day-night temperature differences that increase the concentration of sugars and nutrients. These farms are ideal for organic farming, as the natural isolation allows avoiding pesticides and synthetic fertilizers. The resulting products are in demand in niche markets, especially among consumers looking for healthy and natural products. However, upland farmers face significant challenges. Difficult access to markets makes transportation difficult and lowers profitability. Mechanization is limited due to the steep slopes, and frequent climatic variations increase the risk of frosts or drought. To overcome these obstacles, farmers use adaptive techniques such as terrace cultivation, which prevents erosion, and the use of greenhouses or tunnels to extend the growing season. Drip irrigation systems are an effective solution for saving water and protecting the soil.

Mountain farms offer premium products that sell for higher prices due to their superior quality

and organic origin. In addition to selling fresh vegetables, farmers can develop derivative products such as pickles, preserves or aromatic teas that add value to their production. These farms also have a significant social impact, helping to create jobs in isolated communities and preserving local agricultural traditions [18-19].

Tips for success - To be successful, mountain farms should diversify production, growing more types of vegetables and herbs to reduce the risks associated with monocultures. Ecological certification is essential for attracting premium consumers, and capitalizing on the tourism potential of the area through agritourism can bring additional income. Investments in infrastructure such as greenhouses, irrigation systems and processing facilities can be financed through European funds, thus supporting the sustainable development of the farm. This combination of adaptability, sustainability and innovation makes the mountain vegetable farm an example of modern agriculture in harmony with nature [21-24].

2. Literature review

2.1. Challenges in Mountain Agriculture

Mountain agriculture faces unique challenges that stem from its geographical and climatic constraints. Jodha (2000) [11] highlights the limited availability of arable land, steep slopes, and poor soil fertility as primary obstacles. Additionally, unpredictable weather patterns and the risk of erosion intensify the difficulty of farming in these regions [12]. Transportation and market access also pose significant hurdles, limiting farmers' ability to sell their produce effectively.

2.2. Productivity Calculations in Mountain Farming

The productivity of mountain farms is inherently lower than that of lowland farms due to shorter growing seasons and harsher

environmental conditions. Pretty (2008) [16] emphasizes that yield calculations must incorporate these limitations while identifying opportunities for maximizing output through sustainable practices. For example, Zomer et al. (2009) [25] illustrate how efficient irrigation systems can enhance water use, improving productivity despite limited resources. Furthermore, Reynolds and Tuberosa (2008) [17] suggest using drought-tolerant crops to overcome the impact of climatic stress on yield.

2.3. Sustainable Practices in Mountain Agriculture

Sustainability in mountain farming is vital to preserving ecological balance and ensuring long-term productivity. Bavec and Bavec (2015) [3] underline the importance of adopting organic farming techniques, which minimize chemical use and enhance soil health. Intercropping, as described by Hauggaard-Nielsen and Jensen (2005) [10], supports biodiversity and improves nutrient cycling, which are essential for soil conservation in mountainous areas. Agroforestry practices, detailed by Meijer and Catacutan (2015) [14], further aid sustainability by integrating tree crops that provide ecological stability and economic returns.

2.4. Economic and Social Impact

Mountain farming has significant social and economic implications, particularly for rural communities. Barrett and Swallow (2006) [2] explain how mountain farms can alleviate poverty by creating employment opportunities and fostering economic development. Diversifying activities, such as incorporating agrotourism, can significantly enhance income. Additionally, Leakey (2012) [13] highlights the cultural importance of mountain agriculture in preserving traditional farming knowledge and practices, which strengthens community resilience.

Table 1. Comparative Table: Productivity of Vegetables in Lowland vs Mountain Areas

Aspect	Lowland area	Mountain area
Growing season	Long (approximately 8-10 months/year)	Short (approximately 5-6 months/year)
Yield per hectare (tons)	High (15-40 tons/ha, depending on the vegetable)	Low (5-15 tons/ha, depending on the vegetable)
Product quality	Standard	Superior (more flavorful, richer in nutrients)
Resistance to extreme climatic conditions	Medium	High (greater adaptability to cold and harsh conditions)
Crop diversity	Very high	Moderate
Use of chemical inputs	High (pesticides, fertilizers)	Very low (ideal for organic farming)
Production costs	Lower due to mechanization	Higher due to difficult access and lack

		of mechanization
Market price potential	Moderate	High (premium products)

Table 2. Detailed Comparative Table: Vegetable Productivity and Characteristics

Vegetable	Yield in Lowland (tons/ha)	Yield in Mountain (tons/ha)	Growing Season in Lowland	Growing Season in Mountain	Nutritional Value in Mountain
Potatoes	30-40	15-20	Long (8-10 months)	Short (5-6 months)	High (rich in vitamin C)
Cabbage	25-30	10-15	Long (8-10 months)	Short (5-6 months)	High (antioxidants, fiber)
Carrots	20-25	10-15	Medium (6-8 months)	Short (5-6 months)	High (beta-carotene)
Beets	20-30	10-20	Medium (6-8 months)	Short (5-6 months)	High (antioxidants, nitrates)
Radishes	10-15	5-8	Short (4-5 months)	Very short (3-4 months)	High (crisp texture)
Lettuce	10-12	5-7	Short (4-5 months)	Very short (3-4 months)	High (vitamins A and K)
Spinach	8-10	4-6	Short (4-6 months)	Very short (3-4 months)	High (iron, vitamin C)
Onions	20-25	8-12	Medium (6-8 months)	Short (4-5 months)	High (flavonoids)
Garlic	15-20	6-8	Medium (6-8 months)	Short (4-5 months)	High (allicin, antioxidants)

3. Calculation of the area of land and the amount of water required for vegetable crops on a mountain farm

This synthesis details calculation methods for determining the required land area, as well as the amount of irrigation water, for the main vegetables grown in a mountain vegetable farm [15].

1. Main steps for calculating the area and required resources

For each vegetable species, the process involves the following steps:

1. Determination of the annual gross requirement in the kitchen (Nab), according to the production plan.

2. Adjustment for storage losses (Nad):

$$Nad = Nab \times (1 + P) \quad (1)$$

Where:

Nab = Annual gross requirement [kg]

P = Percentage of losses during storage [%]

3. Calculation of the minimum required area (Smin):

$$Smin = Nad / Pha \times 10000 \quad (2)$$

Where:

Nad = Gross requirement adjusted for losses [kg]

Pha = Productivity per hectare [kg/ha]

4. Determination of adopted area (Sa): The actual area allocated to the crop, rounded to a practical size for farms (eg 10 x 10 m).

5. Calculation of real production (Pr):

$$Pr = Sa \times Pha / 10000 \quad (3)$$

6. Determination of the amount of water for irrigation (Qa):

$$Qa = Sa \times Ni / 10000 \quad (4)$$

Where:

Sa = Adopted area [m²]

Ni = Irrigation rate [m³/ha]

3.1. Calculation example for main crops

Potatoes

- Nab = 4000 kg

- P = 20.0%

$$Nad = Nab \times (1 + P) = 4000 \times (1 + 0.2) \quad (5)$$

$$Smin = Nad / Pha \times 10000 \quad (6)$$

Sa = 3000 m² is adopted, and the actual production becomes:

$$Pr = Sa \times Pha / 10000 = 4800 \text{ kg} \quad (7)$$

Amount of water required:

180 m³/ha (April-May), 90 m³/ha (June), 45 m³/ha (July)

Onions

- Nab = 500 kg

- P = 20.0%

$$Nad = Nab \times (1 + P) = 500 \times (1 + 0.2) \quad (8)$$

$$Smin = Nad / Pha \times 10000 \quad (9)$$

Sa = 150 m² is adopted, and the actual production becomes:

$$Pr = Sa \times Pha / 10000 = 600 \text{ kg} \quad (10)$$

Amount of water required:

4.5 m³/ha (March-April), 2.25 m³/ha (May-June)

Tomatoes

- Nab = 700 kg

- P = 30.0%

$$Nad = Nab \times (1 + P) = 700 \times (1 + 0.3) \quad (11)$$

$$Smin = Nad / Pha \times 10000 \quad (12)$$

Sa = 170 m² is adopted, and the actual production becomes:

$$Pr = Sa \times Pha / 10000 = 935 \text{ kg} \quad (13)$$

Amount of water required:

5.1 m³/ha (March-April), 2.55 m³/ha (May-June),
1.275 m³/ha (July-August)

Eggplant

- Nab = 1000 kg

- P = 5.0%

$$Nad = Nab \times (1 + P) = 1000 \times (1 + 0.05) \quad (14)$$

$$Smin = Nad / Pha \times 10000 \quad (15)$$

Sa = 270 m² is adopted, and the actual production becomes:

$$Pr = Sa \times Pha / 10000 = 1080 \text{ kg}$$

Amount of water required:

8.1 m³/ha (March-April), 4.05 m³/ha (May-June),
2.025 m³/ha (July-August)

Carrots

- Nab = 400 kg

- P = 25.0%

$$Nad = Nab \times (1 + P) = 400 \times (1 + 0.25) \quad (16)$$

$$Smin = Nad / Pha \times 10000 \quad (17)$$

Sa = 200 m² is adopted, and the actual production becomes:

$$Pr = Sa \times Pha / 10000 = 500 \text{ kg} \quad (18)$$

Amount of water required:

6 m³/ha (March-April), 3 m³/ha (May), 1.5 m³/ha (June)

Celery

- Nab = 400 kg

- P = 20.0%

$$Nad = Nab \times (1 + P) = 400 \times (1 + 0.2) \quad (19)$$

$$Smin = Nad / Pha \times 10000 \quad (20)$$

Sa = 200 m² is adopted, and the actual production becomes:

$$Pr = Sa \times Pha / 10000 = 500 \text{ kg} \quad (21)$$

Amount of water required:

6 m³/ha (April-May), 3 m³/ha (June)

Parsley

- Nab = 100 kg

- P = 15.0%

$$Nad = Nab \times (1 + P) = 100 \times (1 + 0.15) \quad (22)$$

$$Smin = Nad / Pha \times 10000 \quad (23)$$

Sa = 40 m² is adopted, and the actual production becomes:

$$Pr = Sa \times Pha / 10000 = 120 \text{ kg} \quad (24)$$

Amount of water required:

1.2 m³/ha (March-April), 0.6 m³/ha (May)

Table 3. Summary table

Vegetables	Nab (kg)	Nad (kg)	Smin (m ²)	Sa (m ²)	Pr (kg)	Amount of water required (m ³ /month)
Potatoes	4000	4800	3000.0	3000	4800	180 (April-May), 90 (June), 45 (July)
Onions	500	600	150.0	150	600	4.5 (March-April), 2.25 (May-June)
Tomatoes	700	910	165.45	170	935	5.1 (March-April), 2.55 (May-June), 1.275 (July-August)
Eggplants	1000	1050	262.5	270	1080	8.1 (March-April), 4.05 (May-June), 2.025 (July-August)
Carrots	400	500	200.0	200	500	6 (March-April), 3 (May), 1.5 (June)
Celery	400	480	192.0	200	500	6 (April-May), 3 (June)
Parsley	100	115	38.33	40	120	1.2 (March-April), 0.6 (May)

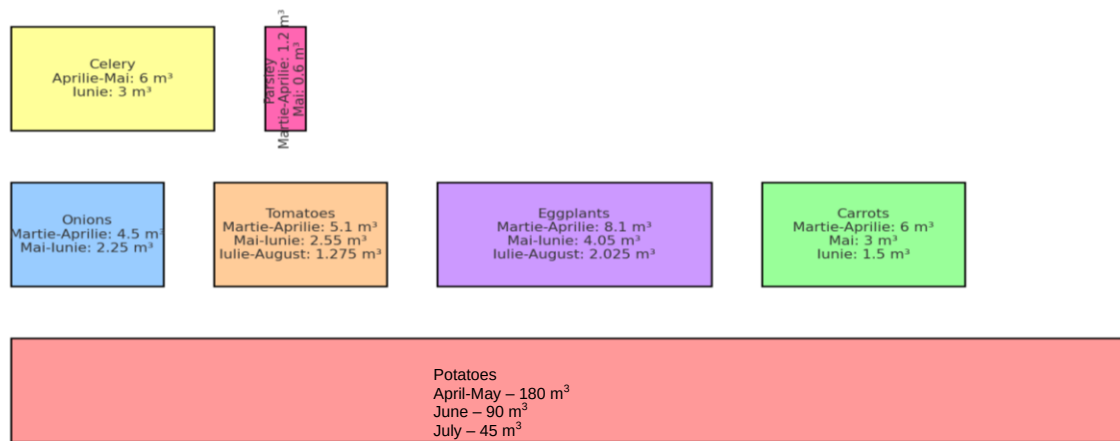


Fig. 1. Water needs per plot

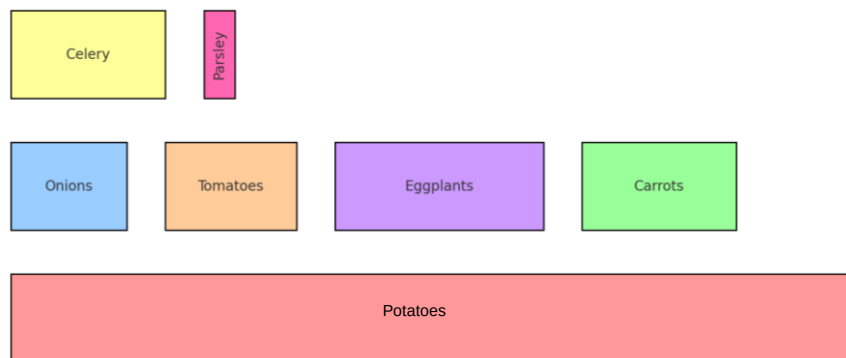


Fig. 2. Compact farm layout

Conclusions

Productivity and Quality: Mountain vegetable farming yields are lower compared to lowland regions due to shorter growing seasons and challenging terrain. For instance, carrots yield 10-15 tons/ha in mountainous areas versus 20-25 tons/ha in lowlands. However, the quality of produce, enriched with antioxidants and nutrients, positions mountain vegetables as premium products.

Sustainability: The isolated nature of mountain farming promotes organic practices with minimal chemical input, aligning with global trends towards environmentally conscious agriculture.

Adaptation Techniques: Successful farms implement adaptive methods such as terracing to prevent soil erosion, using greenhouses to extend growing seasons, and employing drip irrigation to conserve water resources. For example, adopting terraced plots for potatoes with an allocated 3000 m² resulted in a real production of 4800 kg while optimizing water usage.

Economic Potential: Despite higher production costs, mountain farms benefit from niche markets, capitalizing on the superior quality of their products and increasing demand for organic goods.

Social Impact: Mountain farming fosters rural development by creating employment opportunities and preserving agricultural traditions in remote areas. Diversifying activities into agrotourism further enhances economic stability.

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