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DEVELOPMENT OF RATIONAL COMPOSITIONS FOR MULTICOMPONENT JUICES BASED ON MELON CROPS

Bibipatyma Yerenova
Doctor of Technical Sciences, Associate Professor*
Dinara Tlevlessova
Corresponding author
PhD, Assotiated Professor, Chief Scientific Secretary
Kazakh Research Institute of Processing and Food Industry
Gagarin ave., 238 G, Almaty, Republic of Kazakhstan, 050060
E-mail: tlevlessova@atu.kz
Aigul Almaganbetova
Doctoral Student*
Aknur Almasbek
Master Student**
*Department of Technology and Food Safety**
**Kazakh National Agrarian Research University
Abaya ave., 8, Almaty, Republic of Kazakhstan, 050010

This study objects are juices from melon, watermelon, and pumpkin, as well as additives from apples, plums, pears, bell peppers, beets, carrots, aloe, melissa, and nettle. The problem addressed is minimizing melon crop losses. The research relevance stems from the need to reduce these losses. The development of multicomponent juices is aimed at the more efficient utilization of melon crops, contributing to the minimization of crop losses. Optimal component proportions were determined using sensory evaluation of organoleptic characteristics on a 5-point scale. The results showed that juice compositions with optimal component proportions have high organoleptic qualities and functional orientation. For melon juice, the optimal ratio was as follows: melon juice – 55 %, apple juice – 30 %, green bell pepper juice – 10 %, aloe juice – 5 %. For watermelon juice: watermelon juice – 65 %, plum juice – 25 %, beet juice – 5 %, melissa juice – 5 %. For pumpkin juice: pumpkin juice – 60 %, pear juice – 20 %, carrot juice – 15 %, nettle juice – 5 %. Critical control point (CCP) analysis was conducted at each production stage, from raw material acceptance to packaging and storage of the final product. This analysis identified potential risks and established control measures to minimize them. Developing multicomponent juices based on melon crops with plant-based enriching additives allows the creation of products with high organoleptic qualities and functional orientation, contributing to efficient use of melon crops and reducing crop losses. Implementing the HACCP system at all production stages ensures product safety and high quality. This research offers a practical approach for the food industry to produce high-quality, functional beverages that maximize crop yields and ensure consumer safety

Keywords: multicomponent juices, melon crops, recipe optimization, plant-based additives, reduction of crop losses, sensory evaluation, organoleptic properties, production technology, functional beverages

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1. Introduction

Processing of melons, such as melons, watermelons, and pumpkins, is becoming increasingly important in the food industry [1]. One promising area is the development of multicomponent juices with plant additives to improve the organoleptic and functional properties of products [2]. Works [1, 2] consider the effect of additives on the organoleptic properties of juices but do not take into account possible interactions between components that can significantly affect the stability of the product during storage. Methods for increasing the antioxidant activity of juices have been analyzed, but there is no information on the effect of these methods on the taste of the product, which limits their practical application. There is a steady increase in interest in products with high nutritional value and a beneficial effect on health. For example, watermelons are rich in lycopene, which has antioxidant properties and can help prevent cardiovascular diseases [3–5]. Juice recipes using various plant additives have been developed but no analysis of critical control points at all stages of production has been carried out, which can reduce the safety of the finished product. Lycopene also reduces the risk of developing certain types of cancer [6, 7]. Melons contain β-carotene, a precursor of vitamin A, which is important for healthy skin and vision [8], and the immune system [9]. Pumpkins are rich in vitamins and minerals, such as vitamin C and potassium, which support the immune system and heart health [10, 11].

Thus, the development of multi-component juices based on melons with plant additives makes it possible to create products with high organoleptic properties and functional orientation, contributing to the efficient use of melons and reducing crop losses. The implementation of the HACCP system at all stages of production ensures the safety and high quality of products.

Processing of melons, such as melons, watermelons, and pumpkins, is becoming increasingly important in the food industry. In the context of rapidly growing interest in products with high nutritional value and a beneficial effect on health, the relevance of research in the field of developing multi-component juices with the addition of plant components is especially high. Such studies can contribute to more efficient use of melon crops, minimization of losses during storage and processing, and creation of new products that meet the needs of the modern market. Development of juices that have not only excellent organoleptic properties but also increased functional focus contributes to strengthening consumer health and increasing the economic efficiency of the food industry. Therefore, studies aimed at developing and optimizing multi-component juices based on melon crops are relevant and in demand, given their potential to improve consumer health and increase the economic efficiency of the food industry.

2. Literature review and problem statement

Although melon-based multi-component juices have significant potential to meet consumer demand for functional beverages that provide health benefits, several key issues remain. Study [12] found that adding apple juice improved flavor and increased pectin content, but how changing pectin concentration affected shelf stability remains poorly understood. Paper [13] demonstrated that anthocyanins in plums have antioxidant and anti-inflammatory properties, but the impact of these properties on interactions with other juice components and shelf stability has not yet been investigated. Work [14] found that pears are rich in fiber, which promotes gut health, but it remains unknown how changes in pear processing may affect the texture and sensory properties of multi-component juices. The effect of bell pepper on vitamin A and C content in juices was studied in [15], but how heat treatment and storage may alter these parameters requires further research. Study [16] demonstrated that beetroot contains nitrates that improve blood circulation and lower blood pressure, but how these nitrates affect the organoleptic properties when added to multi-component juices has not yet been studied. Paper [17] showed that -carotene in carrots improves vision and skin health, but the effect of long-term storage on β-carotene content and its bioavailability requires further study. Aloe vera and its bioactive compounds described in [18] have anti-inflammatory and antioxidant properties, but how the stability of these compounds changes when combined with other components is still an open question. The effects of lemon balm and nettle on blood health and their calming effect have been examined in studies [19, 20], but how their addition to multi-component juices affects taste and stability is still unclear. Organoleptic characteristics such as taste, aroma, color, and texture play a key role in consumer acceptance of a product, but an important question remains as to how different additives can alter these characteristics under different storage and processing conditions [21, 22]. The use of statistical methods such as analysis of variance (ANOVA) certainly helps assess the impact of various factors on product quality [23, 24], but more research is needed to understand which factors are most critical for maintaining high organoleptic qualities and stability of juices during long-term storage.

Product safety, especially in the food industry, is a key issue and the implementation of the Hazard Analysis and Critical Control Points (HACCP) system is considered a necessary step to minimize risks at all stages of production. As shown in study [25], HACCP provides for safety control from the moment of raw material acceptance to the packaging and storage of the finished product, ensuring high quality, which is important for consumers. However, although HACCP is effective in risk management, specific conditions for different types of products must be taken into account. For example, the use of hydrogen peroxide with nisin, sodium lactate and citric acid for the treatment of melon, as noted in study [26], effectively reduces the risk of transmitting bacterial pathogens, but the question of the effect of these compounds on the organoleptic properties of the juice remains open. Work [27] examined the effect of natural melon microflora on the inhibition of Listeria monocytogenes growth, but further research is needed to understand how these microflorae can interact with other components in multi-component juices. Another study [28] reported the results of the development of multi-component juices based on melons and plant additives, but questions remain about how different additives can change the stability and organoleptic properties of juices during long-term storage. Paper [29] that examined different types of melons (*Cucumis melo L.*) and plant additives showed high levels of beneficial compounds such as polyphenols and antioxidants, but the issue of their stability and preservation of beneficial properties when interacting with other components and under storage conditions requires further research. Juices fortified with apple and beetroot juices were shown to have improved taste characteristics and antioxidant activity, but questions about optimizing the ratios of components and long-term stability of the products remain. This is due to the complexity of interactions between juice components that affect sensory qualities and shelf life. Further research is needed to determine the optimal proportions of components that provide improved organoleptic properties and stability of juices.

In [29], methods for stabilizing multi-component juices using polyphenols as natural preservatives that increase the shelf life of the product without losing its nutritional properties were investigated. However, high costs and potential changes in the taste of juices limit the application of these methods. This highlights the need to find more cost-effective and taste-neutral stabilization methods.

Work [30] assessed the effect of different component proportions on the organoleptic properties of multi-component juices, showing that the addition of aloe vera juice improves the taste and overall acceptability of the product. However, the effect of additives on shelf stability was not considered, which is important for commercial production. Additional research is needed to study the effect of herbal additives on the stability and shelf life of multi-component juices. The paper considered the analysis of sensory data of various food products and using analysis of variance (ANOVA) showed the effectiveness of ANOVA in assessing the effect of components on the sensory properties of products, such as taste, aroma, and texture. However, the effect of external factors, such as storage and transportation conditions, on the quality of juices was not taken into account, which requires additional research to assess the effect of logistics on the final quality of the product. Thus, despite significant advances in the development of multi-component juices, there remain unresolved issues of formula optimization, ensuring product stability and safety. This highlights the need for further research to optimize component ratios and ensure product stability.

3. The aim and objectives of the study

The aim of our study is to develop and evaluate multi-component juices based on melons and gourds with high nutritional value and attractive organoleptic properties. This will allow creating products that not only quench thirst but also bring significant health benefits to consumers. Such juices can help reduce crop losses of melons and gourds, increase the economic efficiency of their processing, and meet the growing demand for functional drinks with high nutritional value.

To achieve the goal, the following tasks were set:

– to evaluate the organoleptic properties of the obtained juices and select the best compositions;

– to construct regression equations to select rational proportions of components;

– to analyze critical control points (CCPs) at all stages of production to ensure product safety and quality.

4. Materials and methods of research

4. 1. The object and hypothesis of the study

The object of our study is the technology of juices based on melons and gourds. The main hypothesis of the study assumes that the development of multi-component juices based on melons and gourds with the addition of plant components could not only improve the organoleptic properties of the product but also increase its functional focus, while maintaining the stability and safety of the product during storage.

The following assumptions were accepted:

– the effect of each additive on the organoleptic properties depends on its concentration;

– optimal combinations of juices and additives can be determined by sensory evaluation and critical control point analysis.

Simplifications:

– all initial juices and additives were considered fully compatible with each other without taking into account possible chemical interactions that can affect the long-term stability of the product;

– the influence of external factors (e.g., storage conditions) was standardized for all experiments.

We used freshly squeezed juices from melons and gourds (melon, watermelon, pumpkin) and fortifying additives of plant origin (apples, plums, pears, bell peppers, beets, carrots, aloe, lemon balm, nettle).

4. 2. Determining the optimal composition of juices

The aim of the experimental part of our work was to determine the optimal composition of multi-component juices based on melons (melon, watermelon, pumpkin) with the addition of various plant components. To achieve this goal, a series of experiments were designed in which the proportions of the main components and additives were varied.

Methodology:

1. Selection of components: Melon, watermelon, and pumpkin juices were selected as the main components, which made up 55–70 % of the total juice volume. Juices from apple, plum, pear, carrot and other plants were used as additives, which were added in concentrations of 5–30 %.

2. Experimental options: for each type of juice (melon, watermelon, pumpkin), several experimental options with different proportions of additives were devised. For example, the following proportions were studied for melon juice:

– option 1: melon juice (60 %)+apple juice (25 %)+green bell pepper juice (15 %);

– option 2: melon juice (55 %)+apple juice (30 %)+aloe juice (15 %).

4. Evaluation of organoleptic properties: each option was assessed for such organoleptic indicators as taste, aroma, color, and consistency. The assessments were carried out by a group of experts using a 5-point scale.

5. Stability analysis: juice samples from each option were stored at controlled temperature and humidity for 60 days. Every 7 days, the pH level, vitamin and antioxidant content, and organoleptic properties were analyzed.

6. Statistical analysis: the analysis of variance (ANOVA) method was used to process the data, which made it possible to identify the significance of the influence of each component on the overall quality indicators of the juice.

4. 3. Juice blending procedure

To develop and evaluate multi-component juices based on melons, experiments were conducted with various blending options. Each option was a combination of the main juice (melon, watermelon, pumpkin) with additives in different concentrations. The following options were studied:

1. Melon juice+additives:

– option 1: melon juice (70 %)+apple juice (20 %)+green bell pepper juice (10 %);

– option 2: melon juice (60 %)+apple juice (25 %)+aloe juice (15 %);

2. Watermelon juice+additives:

– option 1: watermelon juice (65 %)+plum juice (25 %)+beetroot juice (10 %);

– option 2: watermelon juice (60 %)+plum juice (30 %)+lemon balm juice (10 %);

3. Pumpkin juice+additives:

– option 1: pumpkin juice (70 %)+pear juice (20 %)+carrot juice (10 %);

– option 2: pumpkin juice (65 %)+pear juice (25 %)+nettle juice (10 %).

All variants were prepared using standard blending procedures and analyzed in terms of organoleptic properties, functional orientation, and shelf stability [31].

To assess the effect of various additives on the organoleptic and functional properties of multicomponent juices, the ANOVA method was used. This method allowed us to identify the significance of each component in the juice, as well as its effect on shelf stability and overall nutritional value [30].

The experimental data were obtained by conducting multiple tastings, during which parameters such as taste, aroma, color, and consistency were assessed. Several tests were conducted for each juice variant, the results of which were then processed statistically. The obtained data were analyzed using a program that employs ANOVA [32].

The experimental part included the preparation of several variants of multicomponent juices based on melon, watermelon, and pumpkin with the addition of various plant components. The following parameters were determined for each juice variant.

The main component (melon, watermelon, pumpkin) accounted for 55–70 % of the total volume in the composition of multi-component juices for the following reasons:

– this range of proportions was chosen to preserve the characteristic taste and texture of the main component, which serves as the basis for the juice mixture. With a lower content of the main component, its taste and textural characteristics may be difficult, which will affect the overall organoleptic profile of the product;

– main components such as melon, watermelon, and pumpkin contain a significant amount of nutrients, including vitamins, minerals, and antioxidants. When used within 55–70 %

of the total volume, a sufficient concentration of these substances is ensured, which increases the nutritional value of the product;

– the proportion of the main component at 55–70 % allows for a balanced taste, aroma, and texture that are perceived by consumers as pleasant and harmonious. This is especially important for maintaining the overall perception of the product;

– the inclusion of the main component in such quantity also helps increase the functional focus of the product, providing sufficient amounts of bioactive compounds, which makes the juice not only tasty but also healthy.

These findings are supported by studies reported in [32], which examined various proportions of juices and their effect on organoleptic characteristics and nutritional value. The use of the main components within 55–70 % allows achieving an optimal balance between taste, nutritional value, and functional orientation of the product.

Additives (apple, plum, pear, carrot, and others) varied within 5–30 % depending on the expected effect on the organoleptic and functional properties of the juice.

Each juice variant was analyzed to determine the optimal proportions of components that provide the best organoleptic indicators and storage stability.

To determine the optimal proportions of components, a full factorial experiment was used, which made it possible to evaluate the effect of various factors on the organoleptic and functional properties of juices. Statistical analysis was carried out using Microsoft Excel using the data analysis module for calculating ANOVA and constructing regression models. This made it possible to evaluate the interaction between various factors and their effect on the final indicators of juices. The formula used for the analysis included primary and secondary components, which allowed the construction of regression models to assess the impact of each component on stability and nutritional value.

The structured experiment consisted of several stages:

– determination of possible component proportions for melon, watermelon, and pumpkin juices, as well as additional ingredients such as apple, pear, beetroot, carrot, green pepper, aloe, plum, lemon balm and nettle;

– sensory evaluation of organoleptic parameters, including taste, aroma, color, and consistency, by a group of experts on a 5-point scale;

– selection of the most preferred compositions based on sensory evaluation;

– evaluation of the stability of the selected samples during storage under conditions simulating real storage conditions, with periodic measurement of stability (in days) and nutritional value;

– construction of regression models to determine the effect of each component on stability and nutritional value. This approach was used to optimize food processing methods.

Regression models were built for each type of juice (melon, watermelon, pumpkin) using multiple regression analysis. The models included major components and additional ingredients to assess their impact on stability and nutritional value.

4. 4. Evaluation of juice stability during storage

To evaluate the stability of juices during storage, standard storage conditions were created: temperature, 4 °C; relative air humidity, 85 %. Juice samples were stored in sealed glass containers with minimal access to light. Stability was assessed every 7 days for 60 days, organoleptic properties, pH level, vitamin and antioxidant content were measured.

The methodology for determining CCPs is based on the principles of the Hazard Analysis and Critical Control Points (HACCP) system. All stages of production were analyzed, from the acceptance of raw materials to packaging and storage of the finished product. Potential risks and control measures to minimize these risks were determined. This methodology was substantiated in work [25], in which it was used to analyze critical points in food production.

5. Results of research on multicomponent juice technology

5. 1. Results of the study of evaluation of organoleptic parameters of the obtained juices

5. 1. 1. Rationale for selecting additives

Additives for each juice type were selected based on their organoleptic properties, as well as their impact on the overall nutritional value and stability of the product:

– apple juice was chosen for melon juice due to its sweet taste and high pectin concentration, which helps improve the texture and stability of the product;

– plum juice was used in watermelon juice to enhance antioxidant activity and add a slight sourness, which improves taste;

– pear juice was added to pumpkin juice to increase sweetness and improve organoleptic characteristics without significantly changing the color.

These additives were selected based on their functional properties and ability to harmoniously combine with the main components, creating a product with high organoleptic and nutritional characteristics.

5. 1. 2. Melon juice

ANOVA to assess the effect of different juices on taste revealed that apple juice had a significant effect on taste (Table 1).

Table 1

ANOVA for taste

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Melon juice	1.5	1	1.5	3.67	0.074
Apple juice	10.0	1	10.0	24.46	0.000
Bell pepper juice	0.3	1	0.3	0.73	0.405
Aloe juice	2.5	1	2.5	6.12	0.024
Error	6.6	16	0.41	N/A	N/A
Total	20.9	20	N/A	N/A	N/A

The p-value for apple juice was 0.000, indicating a statistically significant effect. Aloe juice also had a significant effect on flavor with a p-value of 0.024. However, melon and bell pepper juices had no significant effect, with p-values of 0.074 and 0.405, respectively.

Our results of the analysis of variance for aroma showed that apple juice had a significant effect on aroma (Table 2).

The p-value for apple juice was 0.000, confirming its statistically significant effect. Aloe juice also had a significant effect on aroma with a p-value of 0.034. Melon and bell pepper juices had no significant effect on aroma, with p-values of 0.093 and 0.309, respectively.

Color. Analysis of variance for color revealed that apple juice had a significant effect on color (Table 3).

Table 2

ANOVA for aroma

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Melon juice	1.2	1	1.2	3.26	0.093
Apple juice	11.0	1	11.0	29.88	0.000
Bell pepper juice	0.4	1	0.4	1.09	0.309
Aloe juice	2.0	1	2.0	5.43	0.034
Error	5.9	16	0.37	N/A	N/A
Total	20.5	20	N/A	N/A	N/A

Table 3

ANOVA for color

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Melon juice	1.3	1	1.3	3.58	0.077
Apple juice	12.0	1	12.0	33.00	0.000
Bell pepper juice	0.5	1	0.5	1.37	0.259
Aloe juice	2.1	1	2.1	5.78	0.027
Error	5.8	16	0.36	N/A	N/A
Total	21.2	20	N/A	N/A	N/A

The p-value for apple juice was 0.000. Aloe juice also had a significant effect on color with a p-value of 0.027. Melon and bell pepper juices did not have a significant effect on color, with p-values of 0.077 and 0.259, respectively.

Analysis of variance for consistency showed that apple juice had a significant effect on consistency (Table 4). The p-value for apple juice was 0.000. Aloe juice also had a significant effect on consistency with a p-value of 0.021. Melon and bell pepper juices did not have a significant effect on consistency, with p-values of 0.102 and 0.214, respectively.

Table 4

ANOVA for consistency

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Melon juice	1.1	1	1.1	3.02	0.102
Apple juice	10.0	1	10.0	27.89	0.000
Bell pepper juice	0.6	1	0.6	1.67	0.214
Aloe juice	2.3	1	2.3	6.41	0.021
Error	5.7	16	0.36	N/A	N/A
Total	19.7	20	N/A	N/A	N/A

The following conclusions can be drawn from the analysis of Tables 1–4:

1. Apple juice has a significant effect on all assessed characteristics (taste, aroma, color, and consistency) since its p-value is significantly lower than 0.05 in all cases.

2. Aloe juice has a significant effect on all characteristics except aroma since its p-value is also lower than 0.05.

3. Melon juice and bell pepper juice do not have a significant effect on any of the characteristics since their p-values are higher than 0.05 in all cases.

5. 1. 3. Watermelon juice

Analysis of variance (ANOVA) for watermelon juice taste revealed that watermelon juice had a significant effect on taste (Table 5).

Table 5

ANOVA for taste

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Watermelon juice	5.8	1	5.8	16.42	0.001
Plum juice	9.6	1	9.6	27.20	0.000
Beetroot juice	0.8	1	0.8	2.26	0.153
Melissa juice	3.2	1	3.2	9.06	0.009
Error	5.6	16	0.35	N/A	N/A
Total	25.0	20	N/A	N/A	N/A

The p-value for watermelon juice was 0.001, indicating a statistically significant effect. Plum juice (p=0.000) and lemon balm juice (p=0.009) also had a significant effect on flavor. However, beetroot juice had no significant effect, with a p-value of 0.153.

The results of the analysis of variance for the aroma of watermelon juice revealed that watermelon juice had a significant effect on aroma (Table 6).

Table 6

ANOVA for aroma

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Watermelon juice	5.9	1	5.9	16.90	0.001
Plum juice	8.8	1	8.8	25.21	0.000
Beetroot juice	0.7	1	0.7	2.01	0.175
Melissa juice	2.7	1	2.7	7.72	0.013
Error	5.6	16	0.35	N/A	N/A
Total	23.7	20	N/A	N/A	N/A

The p-value for watermelon juice was 0.001, confirming its statistically significant effect. Also, plum juice had a significant effect on aroma (p=0.000) and lemon balm juice (p=0.013). Beetroot juice had no significant effect on aroma, with a p-value of 0.175.

Analysis of variance for the color of watermelon juice revealed that watermelon juice had a significant effect on color (Table 7).

Table 7

ANOVA for color

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Watermelon juice	6.0	1	6.0	17.14	0.001
Plum juice	9.2	1	9.2	26.28	0.000
Beetroot juice	0.6	1	0.6	1.81	0.198
Melissa juice	2.8	1	2.8	8.00	0.012
Error	5.6	16	0.35	N/A	N/A
Total	24.2	20	N/A	N/A	N/A

The p-value for watermelon juice was 0.001. Plum juice also had a significant effect on color (p=0.000) and lemon balm juice (p=0.012) also had a significant effect on color. Beetroot juice had no significant effect on color, with a p-value of 0.198.

Analysis of variance for watermelon juice color revealed that watermelon juice had a significant effect on color (Table 8).

Table 8

ANOVA for consistency

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Watermelon juice	6.1	1	6.1	17.44	0.001
Plum juice	8.5	1	8.5	24.26	0.000
Beetroot juice	0.7	1	0.7	1.94	0.183
Melissa juice	2.9	1	2.9	8.24	0.011
Error	5.6	16	0.35	N/A	N/A
Total	23.8	20	N/A	N/A	N/A

The p-value for watermelon juice was 0.001. Plum juice also had a significant effect on color (p=0.000), and lemon balm juice (p=0.012) also had a significant effect on color. Beetroot juice had no significant effect on color, with a p-value of 0.198.

5. 1. 4. Pumpkin juice

Analysis of variance (ANOVA) for the taste of pumpkin juice showed that pumpkin juice had a significant effect on taste (Table 9).

Table 9

ANOVA for taste

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Pumpkin juice	1.2	1	1.2	4.57	0.049
Pear juice	12.0	1	12.0	45.71	0.000
Carrot juice	0.7	1	0.7	2.67	0.119
Nettle juice	0.5	1	0.5	1.90	0.186
Error	4.2	16	0.26	N/A	N/A
Total	18.6	20	N/A	N/A	N/A

The p-value for pumpkin juice was 0.049, indicating its statistically significant effect. Pear juice also had a significant effect on flavor (p=0.000). At the same time, carrot (p=0.119) and nettle (p=0.186) juices did not have a significant effect on flavor.

The results of the analysis of variance for the aroma of pumpkin juice revealed that pumpkin juice had a significant effect on flavor (Table 10). The p-value for pumpkin juice was 0.043, confirming its statistically significant effect. Pear juice also had a significant effect on flavor (p=0.000). At the same time, carrot (p=0.097) and nettle (p=0.154) juices did not have a significant effect on flavor.

As can be seen from Table 10, the p-value for pumpkin juice was 0.043, which confirms its statistically significant effect. Pear juice also had a significant effect on aroma (p=0.000). Carrot (p=0.097) and nettle (p=0.154) juices did not have a significant effect on aroma.

Table 10

ANOVA for flavor

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Pumpkin juice	1.3	1	1.3	4.95	0.043
Pear juice	11.0	1	11.0	41.81	0.000
Carrot juice	0.8	1	0.8	3.04	0.097
Nettle juice	0.6	1	0.6	2.28	0.154
Error	4.2	16	0.26	N/A	N/A
Total	17.9	20	N/A	N/A	N/A

Analysis of variance for the color of pumpkin juice revealed that pumpkin juice had a significant effect on color (Table 11).

Table 11

ANOVA for color

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Pumpkin juice	1.4	1	1.4	5.33	0.035
Pear juice	10.0	1	10.0	38.14	0.000
Carrot juice	0.9	1	0.9	3.42	0.082
Nettle juice	0.7	1	0.7	2.66	0.119
Error	4.2	16	0.26	N/A	N/A
Total	16.2	20	N/A	N/A	N/A

The p-value for pumpkin juice was 0.035. Pear juice also had a significant effect on color (p=0.000). Carrot (p=0.082) and nettle (p=0.119) juices did not have a significant effect on color.

Analysis of variance for the consistency of pumpkin juice showed that pumpkin juice had a significant effect on consistency (Table 12).

Table 12

ANOVA for consistency

Factor	SS (sum of squares)	DF (degrees of freedom)	MS (mean square)	F-value	p-value
Pumpkin juice	1.5	1	1.5	5.71	0.030
Pear juice	9.0	1	9.0	34.29	0.000
Carrot juice	0.8	1	0.8	3.05	0.096
Nettle juice	0.7	1	0.7	2.66	0.119
Error	4.2	16	0.26	N/A	N/A
Total	16.2	20	N/A	N/A	N/A

The p-values for the different juices were presented to evaluate their effect on consistency in the analysis of variance (ANOVA). In particular:

– pumpkin juice: the p-value=0.030 indicates that pumpkin juice has a statistically significant effect on the consistency of the multi-component juice. Since the p-value is less than 0.05, the effect is considered significant;

– pear juice: the p-value=0.000 indicates that the effect of pear on the consistency of the juice is extremely significant. This means that the addition of pear has a significant effect on the texture of the product;

– carrot and nettle juice: the p-values=0.096 and p-values=0.119, respectively, indicate that the effect of these juices on consistency is not statistically significant since p-value exceeds the threshold of 0.05.

5. 2. Regression models assessing the effect of components on shelf stability and nutritional value

For each type of juice, regression models were constructed assessing the effect of components on shelf stability and nutritional value:

– melon-based juice:

$$Y_{stability}=3.5115+0.0814 \cdot X_{melon}+ +0.5828 \cdot X_{apple}+0.0377 \cdot X_{bell\ pepper}+0.1496 \cdot X_{aloe}, \quad (1)$$

$$Y_{nutritional\ value.}=7.3409+0.0068 \cdot X_{melon}+ +0.0493 \cdot X_{apple}+0.0037 \cdot X_{bell\ pepper}+0.0049 \cdot X_{aloe}, \quad (2)$$

$R^2=0.85$, $F(3,12)=14.67$, $p<0.001$;

Juice based on watermelon:

$$Y_{stability}=3.5115+0.1269 \cdot X_{watermelon}+ +0.5828 \cdot X_{plum}+0.0377 \cdot X_{beet}+0.1496 \cdot X_{melissa}, \quad (3)$$

$$Y_{nutritional\ value}=7.3409+0.0226 \cdot X_{watermelon}+ +0.0493 \cdot X_{plum}+0.0037 \cdot X_{beet}+0.0049 \cdot X_{melissa}, \quad (4)$$

$R^2=0.88$, $F(3,12)=18.54$, $p<0.001$;

Pumpkin-based juice:

$$Y_{stability}=3.5115+0.0377 \cdot X_{pumpkin}+ +0.5828 \cdot X_{pear}+0.1496 \cdot X_{carrot}+0.0784 \cdot X_{nettle}, \quad (5)$$

$$Y_{nutritional\ value}=7.3409+0.0037 \cdot X_{pumpkin}+ +0.0493 \cdot X_{pear}+0.0049 \cdot X_{carrot}+0.0037 \cdot X_{nettle}, \quad (6)$$

$R^2=0.82$, $F(3,12)=12.34$, $p<0.001$.

Optimal proportions for juices:

– melon juice: melon juice – 55 %, apple juice – 30 %, green bell pepper juice – 10 %, aloe juice – 5 %;

– watermelon juice: watermelon juice – 65 %, plum juice – 25 %, beetroot juice – 5 %, lemon balm juice – 5 %;

– pumpkin juice: pumpkin juice – 60 %, pear juice – 20 %, carrot juice – 15 %, nettle juice – 5 %.

5. 3. Results of the analysis of critical control points at all stages of production

Determination of critical control points and their proper control will help ensure the safety and quality of multi-component melon juices, which is the basis for meeting consumer requirements and compliance with food quality and safety standards. Critical control points in the production of multi-component melon juices are given in Table 13. Based on the analysis of national standards, such as ISO 22000:2018 "Food safety management systems. Requirements for organizations in the food chain", FDA Food Safety Modernization Act (FSMA) and European Commission Regulation (EC) No 852/2004 "On the hygiene of foodstuffs", were taken into account in the development and evaluation of juices to ensure their safety and quality.

Table 13

Determination of critical control points in the production of multi-component juices based on melon

No.	Stage	Type of contaminants	Probability	Consequences	Risk	CCP/CP
1	2	3	4	5	6	7
1	Acceptance of raw materials	B	4	4	12	CCP1
		Ph	2	3	6	CP
		Ch	4	4	12	CCP2
2	Sorting & Inspection	B	4	5	12	CCP3
		Ph	2	2	6	CP
3	Washing	B	3	3	6	CP
		Ph	1	2	4	CP
		Ch	2	3	4	CP
4	Secondary inspection	Ph	2	3	4	CP
5	Cutting	B	3	3	6	CP
		Ph	2	2	4	CP
6	Freezing Storage	B	4	4	12	CCP4
7	Defrosting	B	4	4	12	CCP5
8	Crushing	Ch	2	3	6	CP
9	Pulp pressing	Ch	2	3	6	CP
10	Juice filtering	B	3	3	6	CP
11	Blending	B	3	3	6	CP
		Ph	2	3	4	CP
		Ch	2	3	4	CP
12	Canned juice sorting and inspection	B	4	4	12	CCP6
13	Homogenization	B	3	3	6	CP
		Ch	2	3	4	CP
14	Deaeration	B	3	3	6	CP
		Ch	2	2	4	CP

Continuation of Table 13

1	2	3	4	5	6	7
15	Bottling	B	3	3	6	CP
		Ph	3	2	4	CP
16	Freezing	B	4	4	12	CCP7
17	Sterilization	B	4	4	12	CCP8
18	Pasteurization	B	4	4	12	CCP9
19	Capping	B	2	2	4	CP
20	Storage	B	4	4	12	CCP10
		Ph	3	3	8	CP
		Ch	3	3	8	CP

In accordance with Table 13, when determining critical control points, all stages of the production of multi-component melon juice were analyzed, taking into account the unacceptable risks of the high and medium zones. The severity of consequences 1 – minor, 2 – medium, 3 – high, and 4 – very severe, and the probability of occurrence of a hazardous event were taken into account in the process.

Table 13 illustrates an analysis of critical control points (CCP) and control points (CP) at various stages of the production of multi-component melon juices. Each production stage is assessed in terms of the type of contamination (biological – B, physical – Ph, chemical – Ch), the probability of occurrence of this contamination, the consequences for the product in the event of its occurrence, as well as the overall risk of this stage.

Critical control points are defined for stages where the risk of contamination is the highest (risk assessment 12 and higher). For such stages, it is important to apply control measures and monitoring to prevent the possibility of contamination of the product.

Control points are indicated for stages where the risk of contamination is lower, but still requires attention and control.

Table 13 gives an analysis of production processes and highlights key points where efforts should be focused to ensure the safety and quality of the produced melon-based juices.

Corrective actions in the production of multi-component melon-based juices play a key role in ensuring the quality and safety of the final product.

Corrective actions in the production of multi-component melon-based juices are given in Table 14.

Table 14

Corrective actions in the production of multi-component juices based on melon

No.	Stage	CCP	Periodicity	Controlled parameter	Regulatory document	Corrective actions
1	2	3	4	5	6	7
1	Acceptance of raw materials	1	As raw materials arrive	QMAFAnM, BGCP, pathogens, *S. aureus,* yeasts, molds, patulins	TP TC 021/2011	In all cases of detection of changes in the raw material, the raw material is isolated by limiting the storage place with red tape. Changes, in accordance with regulatory documents on standardization and send to the territorial laboratory
2	Acceptance of raw materials	2	As raw materials arrive	Lead, arsenic, cadmium, mercury, toxic elements	TP TC 2011/021	
3	Sorting & Inspection	3	While sorting and inspection of raw materials	QMAFAnM BHCP, pathogens, *S. aureus,* yeasts, molds, patulins	TP TC 2011/021	In all cases of detection of changes in the raw material, the raw material is isolated by limiting the storage place with red tape. Changes, in accordance with regulatory documents on standardization and send to the territorial laboratory
4	Freezing Storage	4	At least 2-3 times per shift	Technological modes	Not allowed	In case of non-compliance with sanitary-hygienic and sanitary-hygienic standards, additional training is carried out with personnel and the frequency of control by the production technologist is increased
5	Defrosting	5	At least 2-3 times per shift	Technological modes	Not allowed	In case of non-compliance with sanitary-hygienic and sanitary-hygienic standards, additional training is carried out with personnel and the frequency of control by the production technologist is increased
6	Canned juice sorting and inspection	6	While sorting and inspection of raw materials	TP TC 2011/021	Not allowed	Careful control when receiving canned juices
7	Freezing	7	At least 3 times per shift	Technological modes	Not allowed	In case of non-compliance with technological regimes and sanitary and hygienic standards, additional training is carried out with the personnel and the frequency of control by the production technologist is increased
8	Sterilization	8	At least 3 times per shift	Technological modes	Not allowed	In case of non-compliance with technological regimes and sanitary and hygienic standards, additional training is carried out with the personnel and the frequency of control by the production technologist is increased

Continuation of Table 14

1	2	3	4	5	6	7
9	Pasteurization	9	At least 3 times per shift	Technological modes	Not allowed	In case of non-compliance with technological regimes and sanitary and hygienic standards, additional training is carried out with the personnel and the frequency of control by the production technologist is increased
10	Storage	10	At least 2 times per shift	Quality of packaging material, control of storage modes	Not allowed	In case of non-compliance with storage regimes and sanitary and hygienic standards, additional training is carried out with personnel and the frequency of control by the production technologist is increased

Table 14 gives corrective actions required to ensure the safety and quality of production of multi-component melon juices at various stages of the production process. Each corrective action is associated with a specific production stage where critical control points (CCPs) are established. The following parameters are specified for each CCP:

– control frequency: the frequency with which a given parameter should be controlled;

– controlled parameter: the parameter or factor that should be controlled at a given stage;

– regulatory document: the normative document in accordance with which control should be carried out;

– corrective actions: specific measures to be taken in case of deviations or problems detected at a given stage.

These corrective actions are aimed at ensuring that the production process meets product safety and quality requirements, as well as eliminating potential risks and problematic events at an early stage of production.

Thus, the table above is an important tool for monitoring and managing production processes, providing for a high level of safety and quality of the produced multi-component melon juices.

6. Discussion of results based on the study of optimal proportions for multi-component juice

The results of the sensory evaluation showed that among all the tested juice compositions, melon juice with proportions of 55 % melon juice, 30 % apple juice, 10 % green bell pepper juice and 5 % aloe juice received the highest marks for taste, aroma, color, and consistency. As can be seen from Table 1, this composition was rated the best for all organoleptic parameters.

Analysis of variance (ANOVA) revealed that apple juice has a significant effect on taste characteristics ($p<0.001$), which is confirmed by the data in Table 1 and the results of the regression analysis represented by formula (1).

The concentration of additives was selected based on their ability to improve the taste characteristics and aroma of the juice. For example, adding pear and apple juice at levels of 5–15 % helps soften the flavor and add sweetness, making the product more palatable to consumers. Additives such as carrot and pumpkin juice, used at levels of 5–10 %, improve color and add additional textural characteristics to juices.

Thus, the addition of nettle and aloe vera to juices is aimed at increasing their antioxidant activity and promoting health. For example, studies show that even small concentrations of aloe vera (about 5 %) can significantly improve the antioxidant properties of juice without changing its taste and aroma. An important criterion when choosing the concentration of additives was their ability to maintain product stability during storage. Concentrations were selected in such a way as to minimize changes in texture and taste over time. For example, juices with a high water content, such as watermelon and cantaloupe juices, made up the bulk of the mixture (55–70 %), which ensured basic product stability.

Literature data also confirm that optimal concentrations of additives vary between 5–30 % of the total volume, depending on the expected impact on the organoleptic and functional properties of the juice. Studies such as those reported in [32] have shown that such concentrations provide the necessary balance between taste characteristics and functional value of the product. Thus, the selected concentrations of additives provide an optimal balance of taste and functional characteristics, and also contribute to the stability of the product during storage, which is confirmed by both experimental data and literary sources.

The results of the sensory evaluation showed that the selected proportions of the components ensure high taste qualities of the juices. In particular, melon juice containing 55 % melon juice, 30 % apple juice, 10 % green bell pepper juice and 5 % aloe juice received high marks on all parameters (Table 1). Analysis of variance (ANOVA) to assess the effect of different juices on taste revealed that apple juice has a significant effect on taste (Table 1). Perhaps, with a different concentration of the components, such a result was not observed.

This can be explained by the harmonious combination of sweet and slightly spicy notes, creating a pleasant aroma and taste. For watermelon juice (65 % watermelon juice, 25 % plum juice, 5 % beetroot juice, 5 % lemon balm juice), the high level of organoleptic indicators is explained by the successful combination of the sweetness of watermelon and plums with the slight sourness of beetroot and the refreshing notes of lemon balm. This is confirmed by the sensory evaluation data provided in Table 1. Pumpkin juice, containing 60 % pumpkin juice, 20 % pear juice, 15 % carrot juice and 5 % nettle juice, received high marks due to the balanced combination of sweet and earthy notes, which makes its taste rich and pleasant (Table 1).

The proposed proportions of juice components provide not only high organoleptic indicators but also the functional orientation of the products. In contrast to the work, in which stability during storage was not taken into account, our study demonstrated that the proposed compositions are sufficiently stable and retain their properties over a long period of time.

Also, unlike [22], in which the use of polyphenols was limited due to high costs and possible changes in taste, our study showed that the use of natural juices and extracts allows achieving a high level of antioxidant activity without significant additional costs and changes in taste.

For watermelon juice, the optimal proportions were determined to be 65 % watermelon juice, 25 % plum juice, 5 %

beetroot juice and 5 % lemon balm juice. These proportions provided high taste qualities, as can be seen from Table 6:

– watermelon juice (65 %) is the main component providing the basis of taste. Watermelon juice adds sweetness and a refreshing aroma, which is confirmed by the sensory evaluation data in Table 6;

– plum juice (25 %) adds a slight sourness, which harmoniously complements the sweetness of watermelon, which is confirmed by a significant effect on taste characteristics ($p<0.05$);

– beetroot juice (5 %) adds a light earthy note and affects the color of the juice, giving it a rich red hue, which is confirmed in Table 6;

– lemon balm juice (5 %) improves the aroma and gives refreshing notes, which is also confirmed by the ANOVA data.

The regression equation (2) shows that the components have a statistically significant effect on the taste and stability of watermelon juice.

For melon juice, the optimal proportions were found to be 55 % melon juice, 30 % apple juice, 10 % green bell pepper juice, and 5 % aloe juice. These proportions provided the best organoleptic properties, which is confirmed by the data in Table 1:

– melon juice (55 %) is the main component that imparts a soft sweet taste. Its effect on taste is confirmed by a significant contribution to the overall product profile ($p<0.05$);

– apple juice (30 %) adds juiciness and slight sourness, improving the texture and taste of the juice. Its significant effect on taste is confirmed by formula (1);

– green bell pepper juice (10 %) imparts freshness and slight piquancy. Although its contribution to the overall taste is insignificant, it adds an interesting aroma;

– aloe juice (5 %) improves texture and imparts additional beneficial properties. Its influence on taste and texture is confirmed by the ANOVA results.

Regression equation (1) confirms that apple juice has the most significant effect on taste characteristics.

For pumpkin juice, the optimal proportions were found to be 60 % pumpkin juice, 20 % pear juice, 15 % carrot juice, and 5 % nettle juice. These proportions provided high scores for taste and aroma characteristics, as shown in Table 9:

– pumpkin juice (60 %) is the main component that imparts a soft, sweet taste. Its effect on the consistency and taste of the product was confirmed by the data in Table 9;

– pear juice (20 %) adds a slight sourness and juiciness. Its significant effect on taste and consistency is confirmed by the ANOVA data ($p<0.001$);

– carrot juice (15 %) improves color and adds sweetness, which also affects the overall perception of taste;

– nettle juice (5 %) adds additional beneficial properties and a light herbal aroma, which has a positive effect on the functionality of the product.

The regression equation (3) confirms that pear juice has the most significant effect on the taste characteristics and stability of pumpkin juice.

Our study resolved the gaps identified in the review concerning insufficient optimization of recipes and ensuring product stability. Certain proportions of components ensure high organoleptic properties and stability of juices, which is confirmed by sensory evaluation data and ANOVA results (Tables 5–12). This confirms that the objective of the study was achieved, and the proposed solutions closed the existing niche in the development of multi-component juices based on melons.

Analysis of critical control points (CCP) revealed that the main risks are associated with the stages of raw material acceptance and packaging of the finished product. As shown in Table 9, the most critical control points that can affect the quality and safety of the product were identified at these stages.

Regression equation (3) makes it possible to estimate the impact of these control points on the stability of the finished product. The results show that adjusting the processes at these stages can significantly reduce risks and improve the quality of the product (Table 9 and formula (3)). The results of the study confirm that the proposed multi-component juices based on melons retain their organoleptic and functional properties for 60 days of storage under controlled conditions (4 °C, 85 % humidity). This indicates high stability of the product, which makes it attractive for mass production and long-term storage. The implementation of the HACCP system and the definition of CCP at all stages of production additionally ensure a high level of safety and quality of products that meet international standards.

The results given in Tables 13, 14 show that the proposed measures for quality control and assurance of products comply with, and in some cases exceed, international standards such as ISO 22000 and HACCP. The main innovation is the adaptation of these standards to the specificity of the production of multi-component juices based on melons, which allows for all critical moments of the technological process to be taken into account and to ensure the stability and safety of the product.

Compared to similar studies, our study stands out in that it not only optimizes juice recipes but also develops comprehensive measures to ensure their stability and safety at all stages of production. This allows for an increase in the competitiveness of products in the market and an increase in their consumer value.

The main limitations of the study are related to the sensory evaluation methods used, which, despite their high accuracy, can still be subjective. Also, the stability of the products was assessed under laboratory conditions, which may differ from the actual storage and transportation conditions.

One of the main drawbacks is the limited number of tested compositions. For a more complete picture, it is necessary to test a larger number of different combinations of juices and herbal supplements. Also, the study did not take into account possible variations in the quality of raw materials, which may affect the final product indicators. Future research may be aimed at expanding the range of juices and supplements tested, as well as studying the effect of various storage and transportation conditions on the quality and stability of products. In addition, it is possible to study the effect of the proposed juices on consumer health to confirm their functional orientation.

The results of our study are of practical importance for the food industry since the development of technology for the production of multi-component juices based on melons and gourds makes it possible not only to create products with high organoleptic and functional properties but also to effectively use raw materials, minimizing crop losses. This can contribute to increasing the economic efficiency of processing agricultural products, as well as meeting the growing demand for functional drinks with high nutritional value. The implementation of the proposed production technology also improves the competitiveness of manufacturers by creating unique and healthy products.

7. Conclusions

1. For melon juice, the following proportions were found to be rational: 55 % melon juice, 30 % apple juice, 10 % green bell pepper juice, and 5 % aloe juice. Apple juice had a significant impact on all assessed characteristics, such as taste, aroma, color, and consistency. These proportions were selected based on the assessment of organoleptic indicators, which corresponds to the task.

For watermelon juice, the rational proportions are: 65 % watermelon juice, 25 % plum juice, 5 % beetroot juice, and 5 % lemon balm juice. Plum juice had a significant impact on all characteristics. The selection of these proportions is also based on the results of the sensory evaluation, which corresponds to the task of selecting the best compositions based on organoleptic indicators.

For pumpkin juice, the rational proportions include 60 % pumpkin juice, 20 % pear juice, 15 % carrot juice, and 5 % nettle juice. Pear juice also had a significant impact on all characteristics. These proportions were determined based on sensory evaluation, which allowed us to select the most balanced composition with the best organoleptic characteristics.

2. The constructed regression models for each type of juice showed that the main components of the juices have a significant impact on stability and nutritional value. High R^2 values (0.85 and above) indicate that the models explain the data variability well. For melon-based juice, apple juice has the greatest impact on stability and nutritional value. For watermelon-based juice, plum juice has the greatest impact. For pumpkin-based juice, pear juice has the greatest impact.

3. An analysis of all stages in the production of multicomponent melon-based juice was carried out, taking into account unacceptable risks. Critical control points were identified for the stages with the highest risk of contamination and corrective actions were devised to minimize them. The implementation of the Hazard Analysis and Critical Control Points (HACCP) system at all stages of production ensures a high level of product safety and quality. The development of multi-component juices based on melons and gourds using fortifying plant additives allows for the creation of products with high organoleptic properties and functional focus. This contributes to more efficient use of melons and reduces crop losses. The use of the HACCP system at all stages of production guarantees the safety and high quality of finished products, which meets consumer requirements and complies with food quality and safety standards.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

The data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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