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MATHEMATICAL MODELLING OF DETERMINING THE DYNAMICS OF THE NUTRITIONAL VALUE CONTENT OF CLASSIC KEFIR AND THREE TYPES OF FLAVORS OF FUNCTIONAL KEFIR

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ABSTRACT

The main purpose of this paper is to conduct mathematical modeling and statistical analyses as a tool for determining the dynamics during the time of the total content of proteins, dry matter, milk fats, and minerals in three flavors of functional kefir and classic kefir.

The functional kefir variants include dietary fiber and flavors: strawberry (CKS), vanilla (CKV), and peach (CKP). A comparison is made against the non-flavored, without dietary fiber, classic kefir (control-CK).

Analyzing the trends in protein, dry matter, and milk fat content over time involved employing regression analysis, with cubic functions fitting the storage data best. Statistical significance ($p < 0.05$, $p < 0.01$, $p < 0.001$) was determined via t-tests, comparing sample values (functional kefir vs. classic kefir) across different storage durations (1st, 7th, 14th, and 21st day). Additionally, essential minerals were evaluated using t-tests and subjected to Principal Component Analysis (PCA).

From the results obtained following the research, the nutritional value of the classic kefir was determined versus the functional kefir, and in the function of the storage dynamics.

Results reveal distinct nutritional profiles in functional kefirs. Protein content varies across storage periods, with vanilla kefir exhibiting unique patterns. Dietary fiber and flavors influence dry matter content, affecting the stability of functional versus control kefirs. Milk fat content differs due to

added ingredients. Essential minerals show minimal differences between functional and control kefirs, except for magnesium and sodium in select cases. PCA highlights mineral relationships.

Keywords: functional kefir; nutritional value; mathematical modeling; statistical analysis; functional model; kefir

1.INTRODUCTION

With the improvement of living standards, increased availability of information, and education regarding the health benefits of consuming healthy and balanced products, food producers are increasingly focusing on the development and production of food products that combine nutritional and health functions, often referred to as functional foods.

Today, various complex commercial starter cultures are used for the industrial production of kefir. Although starter cultures provide stability in the production process, this method has certain drawbacks. The lack of using starter cultures mainly relates to the lack of taste in kefir compared to traditionally produced kefir, due to the microbial composition of kefir grains, the main fermentation metabolites such as lactic acid, CO₂, and ethanol. Through various spectroscopic and chromatographic analyses, the presence of organic acids and volatile compounds has been confirmed, which play a primary role in aroma formation, despite being present in relatively low concentrations. Apart from lactic acid, kefir also contains citric, acetic, propionic, and other organic acids. The main volatile compounds contributing to aroma formation are identified as acetoin, acetaldehyde, and diacetyl (Güzel-Seydim et al., 2020).

The nutritional and chemical composition of kefir is variable and depends on the natural fat content in milk, microbial composition, and the kefir's technological process. The nutritional and chemical composition of kefir mainly consists of proteins, minerals (calcium, phosphorus, magnesium, potassium, sodium, chlorides), essential amino acids (tryptophan, eucine, lysine, valine), vitamins (A, carotene, B1, B2, B6, B12, C, D, E), aromatic compounds (acetaldehyde, diacetyl, acetoin), and trace elements (iron, copper, molybdenum, manganese, zinc) (Guedes et al., 2016).

Additionally, recent research has highlighted the significance of dietary components in the progression of certain health conditions. For instance, studies by (Gavriloska et al., 2022) and (Gavriloska Damjanovska et al., 2018) have explored the role of a low protein diet in the context of chronic kidney disease. Furthermore, (Knights et al. 2023) have demonstrated the effectiveness of Modeling and Optimization with Artificial Intelligence in Nutrition.

Regarding the chemical composition, kefir is predominantly composed of water (90%), followed by sugars (6%), fats (3.5%), proteins (3%), and ash (0.7%). During fermentation, kefir proteins become easily digestible due to the action of acid coagulation and proteolysis. The amino acid profile of kefir includes serine, lysine, alanine, threonine, tryptophan, valine, methionine, phenylalanine, and isoleucine, which are higher in kefir compared to non-fermented milk (Damiana et al., 2017). According to other studies, the amino acid profile of kefir also includes

glutamic amino acid, tyrosine, histidine, alanine, methionine, lysine, and others (Gul et al., 2015). The content of essential amino acids in kefir follows this order: lysine (376 mg/100 g), isoleucine (262 mg/100 g), phenylalanine (231 mg/100 g), valine (220 mg/100 g), threonine (183 mg/100 g), methionine (137 mg/100 g), and tryptophan (70 mg/100 g) (Liutkevičius & Šarkinas, 2014).

2. MATERIAL AND METHODS

The production of classic kefir (CK) without additives and the formulated variants of kefir enriched with dietary fiber and fruit flavors of strawberry (CKS), vanilla (CKV), and peach (CKP) was carried out under industrial conditions at the VEMILK dairy (IMV - Milk Industry Velkovski, village of Kravari, Bitola) (VEMILK Dairy). Commercial starter cultures for kefir production, including lactic acid bacteria and probiotic bacteria in combination with yeasts, were used for the fermentation of pasteurized milk (Kourkoutas et al. 2006; Mei et al. 2014; Nikolaou et al. 2020). Additionally, commercial dietary fiber (fiber gum) and flavors were incorporated into the formulations (Kourkoutas et al. 2006; Mei et al. 2014; Nikolaou et al. 2020).

The parameters subjected to statistical analysis were obtained from the preliminary physicochemical analysis of kefir and encompassed various determinations. The content of proteins was determined using the Kjeldahl method (AOAC International 2016), while the Gerber method was employed to determine fats (Gerber 1892). Dry matter content was assessed by drying samples at 105°C until a constant sample mass was achieved, and mineral content (ash) was determined by incinerating samples at 550-600°C (Association of Official Analytical Chemists [AOAC] 2016).

The chemical methods, are not the primary focus of this study, but rather their results and statistical processing.

Statistical analysis of the data involved calculating mean values and their standard deviations. Testing for statistical differences in mean values of the examined parameters between the control and functional kefir was performed using the t-test with significance levels of $p < 0.05$, $p < 0.01$, and $p < 0.001$ (Student 1908).

To monitor and predict the dynamics of the total content of nutritional values, a regression analysis of the trend as a function over time was performed (Montgomery et al. 2015).

For essential minerals in kefir, in addition to the t-test, a principal component analysis (PCA) was conducted (Jolliffe & Cadima 2016). Furthermore (Jurina et al., 2019) have compared the effectiveness of principal component regression and partial linear squares regression in prediction modeling.

The obtained results are presented in tabular and graphical forms. The statistical processing of the results was performed using an appropriate software package.

3. RESULTS AND DISCUSSION

3.1. Dynamics of protein content in production series of control and functional kefir

The dynamics of protein content in the kefir series, including the classic kefir (CK) and the functional kefirs CKS, CKV, and CKP, are presented through the average protein content in the control and functional production series of kefirs during storage. The standard deviation values are indicated with $\pm$ as deviations from the mean value. The graphical representation of dynamics of

protein content for the CK and CKS series, CKV and CKP, during cooling storage is shown in Figure 1.

The average protein content during storage for the CKS series kefir on the 1st day was 2.919 ± 0.017 , on the 7th day 2.912 ± 0.006 , on the 14th day 3.007 ± 0.008 , and on the 21st day, the protein content was 2.930 ± 0.023 .

The function of dynamics that approximates the values of the protein content in kefir is represented by a cubic function, for CK is $y = 0,0148x^3 - 0,146x^2 + 0,4082x + 2,719$ and for CKJ is $y = -0,0457x^3 + 0,325x^2 - 0,6623x + 3,302$. The functional model for protein content in the production series CK and CKJ during storage (days) is polynomial with $R^2=1$. The protein content for the CK series during 21 days of storage was $M=3.01525$ and $SD=0.0185$, while for the CKJ series, it was $M=2.942$, $SD=0.0135$.

Similarly, during storage and refrigeration of the production series functional kefir with vanilla (sample CKV), the protein content on the 1st day was 2.919 ± 0.017 , on the 7th day 2.912 ± 0.006 , and on the 14th and 21st days 3.007 ± 0.008 , and 2.930 ± 0.023 , respectively.

The functional model for protein content in the CKV production series during storage (days) is polynomial function with order of three. Approximating the protein values in the product is represented by a cubic function, $y = -0,0782x^3 + 0,551x^2 - 1,1228x + 3,601$, with regression coefficient of $R^2=1$. The protein content during 21 days of storage for the CKV series was $M=2.972$, $SD=0.0055$. The addition of vanilla and dietary fiber to the functional kefir with vanilla influenced the overall protein content during storage.

During cold storage of the CKP series, the protein content on the 1st day was 2.980 ± 0.008 , on the 7th and 14th days 2.988 ± 0.001 and 2.966 ± 0.013 , respectively, and on the 21st day, it was 2.862 ± 0.013 . The dynamic function of proteins is represented by a cubic equation $y = -0,0087x^3 + 0,037x^2 - 0,0423x + 2,994$. The functional model for protein content in the CKP production series during storage (days) is polynomial function with order of three with regression coefficient $R^2=1$. The protein content during 21 days of storage for the CKP series was $M=2.949$, $SD=0.008$.

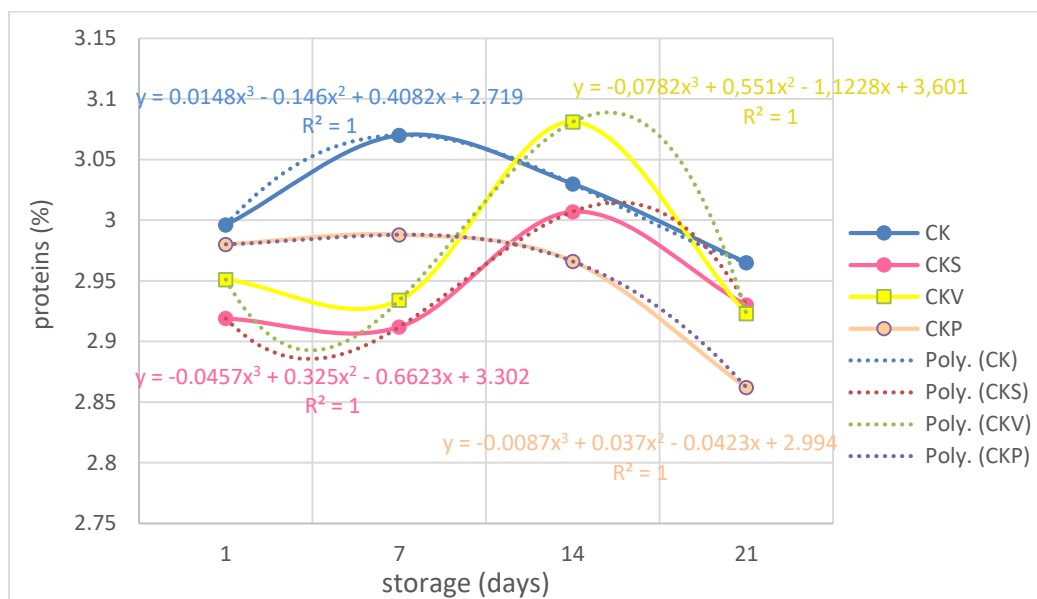


Figure 1: Dynamics of protein content for the production series CK, CKJ, CKV, and CKP during storage.

After conducting the t-test for statistical significance, comparing the functional kefir versus the control kefir, it was found that there is a significant difference between days 7th and 14th in protein content for the sample CK and CKS: $t(1)=42.51$, $p=0.007$; $t(1)=93.80$, $p=0.003$. On the 1st and 21st days, the observed difference was not significant: $t(1)=1.13$, $p=0.231$, $t(1)=6.49$, $p=0.049$. These results confirm the material equilibrium of proteins in the functional kefir.

There is a significant difference on days 1, 7, and 14 in protein content estimates for the CK and CKV series: $t(1)=24.78$, $p=0.013$; $t(1)=104.00$, $p=0.003$; $t(1)=-19.94$, $p=0.016$; $t(1)=1.13$, $p=0.231$. These results confirm that protein content statistically significant differs in the functional production series compared to the control, which is results of the addition of vanilla flavor and dietary fiber.

Proteins in kefir are a crucial component, but water is the main ingredient, thus its addition reduces the protein content in the functional kefir with peach. There is a difference in protein content during storage between control and functional kefir with peach. A significant difference was found on days 7 and 14 in protein content estimates for the sample CK and CKP: $t(1)=182.11$, $p=0.002$; $t(1)=16.41$, $p=0.019$; while a statistically insignificant difference was observed on days 1 and 21, $t(1)=2.72$, $p=0.112$; $t(1)=1.83$, $p=0.159$. The difference in protein content stems from the addition of peach flavor and dietary fiber in the functional kefir CKP.

3.2. Dynamics of total dry matter content in production series of control and functional kefir.

To determine the dynamics of the total dry matter content in the production series of kefir, both control and functional, the average values for dry matter content were calculated during storage for the control kefir. The values for standard deviation were also obtained.

On the first day of cold storage in the production series of CK kefir, the total dry matter content was $11.02 \pm 0.0424\%$, on the 7th day it was $10.96 \pm 0.0113\%$, on the 14th day it was $11.23 \pm 0.0084\%$, and on the 21st day of storage, it reached $10.044 \pm 0.0658\%$. The average total dry matter content over 21 days of storage for the production series CK kefir was $M=10.913$, $SD=0.0320$. The function approximating the total dry matter content for the production series CK is represented by a cubic function: $y = -0,0007x^3 + 0,0197x^2 - 0,1265x + 11,127$ and regression coefficient of $R^2=1$.

In the production series of CKS kefir, on the first day of cold storage, the dry matter content was $12.295 \pm 0.0353\%$, on the 7th day it was $12.100 \pm 0.0141\%$, on the 14th day it was $12.250 \pm 0.0424\%$, and on the 21st day, it ranged from $11.927 \pm 0.0495\%$. The average total dry matter content over 21 days of storage for the production series CKS kefir was $M=12.143$, $SD=0.0353$. The function approximating the total dry matter content for the production series CKJ is represented by a cubic function: $y = -0.0004x^3 + 0.014x^2 - 0.1192x + 12.401$ and regression coefficient of $R^2=1$.

During storage and refrigeration, the total dry matter content in the CKV kefir was $12.365 \pm 0.0354\%$ on the 1st day, $12.150 \pm 0.0141\%$ on the 7th day, $12.465 \pm 0.0071\%$ on the 14th day, and $11.925 \pm 0.0495\%$ on the final analysis day, the 21st day. The average total dry matter content over 21 days of storage for the production series CKV kefir was $M=12.226$, $SD=0.0265$. The function approximating the total dry matter content for the production series CKV is represented by a cubic function: $y = -0.0007x^3 + 0.0227x^2 - 0.1745x + 12.518$.

In the production series of CKP kefir, the total dry matter content on the 1st day was $11.995 \pm 0.0212\%$. During storage and refrigeration, the total dry matter content on the 7th day was $12.255 \pm 0.0212\%$, on the 14th day it was $12.19 \pm 0.00\%$, and on the final testing day, the 21st day, it was $11.73 \pm 0.0141\%$. The average total dry matter content over 21 days of storage for the production series CKP kefir was $M=12.043$, $SD=0.0141$. The function approximating the total dry matter content for the production series CKP is represented by a cubic function: $y = -0.0004x^3 + 0.0258x^2 - 0.4374x + 17.322$. The function for the total dry matter content in functional kefir showed stability during storage.

Graphical representation of the total dry matter content in the production series of CK and CKJ, CKV, and CKP kefir during storage and refrigeration is shown in Figure 2.

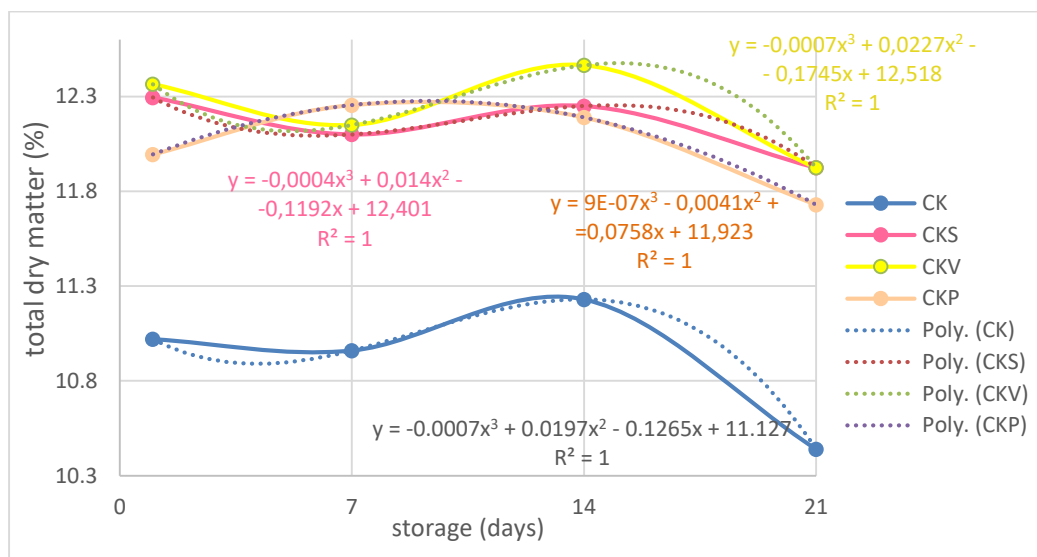


Figure 2: Dynamics of total dry matter content in production series of CK and CKJ kefir during storage

After conducting the t-test for the statistical significance of functional kefir compared to the control kefir, it was determined that a statistically significant difference in the results for the total dry matter content was observed in the production series of CK and CKJ kefir on the 1st, 7th, 14th, and 21st days during storage and refrigeration, with the following values: $t(1)=-255$, $p=0.0012$; $t(1)=-114$, $p=0.0028$; $t(1)=-51$, $p=0.0062$; and $t(1)=-33$, $p=0.0096$, respectively. A statistically significant difference in the total dry matter content was also noted in the production series of CK and CKV kefir on the 1st, 7th, 14th, and 21st days, with the following values: $t(1)=-269$, $p=0.0012$; $t(1)=-119$, $p=0.0027$; $t(1)=-247$, $p=0.0013$; and $t(1)=-33$, $p=0.0096$.

The results of the comparative analysis for the total dry matter content between the control and functional kefir during storage indicate that on the first day of storage, there were variations in the total dry matter content between the production series of control and functional kefir. It can be concluded that the addition of plant fibers to functional kefir affected the overall dry matter content compared to the control kefir.

3.3. Dynamics of total milk fat content in production series of control and functional kefir

The dynamics of milk fat content in the series of kefir CK and CKS, CKV and CKP are shown in Figure 3.

The milk fat content in the production series of CK kefir on the first day was $3.00 \pm 0.034\%$, on the 7th day it was $3.00 \pm 0.0211\%$, on the 14th day it was $3.00 \pm 0.0019\%$, and on the 21st day, the milk fat content was $3.00 \pm 0.0131\%$. The milk fat content during storage from day 1 to day 21 for the CK control kefir series was $M=3.00$, $SD=0.018$. The function of dynamics of total milk fat representing the approximate values for milk fat content is a cubic function, and the same for the production series of CK kefir is $y = 5E-07x^3 - 3E-05x^2 + 0.0002x + 3.0039$.

The average milk fat content on the first day for functional kefir with strawberry CKS was $2.90 \pm 0.0219\%$, during storage on the 7th day it was $2.90 \pm 0.0312\%$, on the 14th day it was $3.00 \pm 0.0035\%$, and on the 21st day it was $3.00 \pm 0.0198\%$. The function representing the approximate values for milk fat content is a cubic function, and the same for the production series of CKS kefir is $y = -0,0001x^3 + 0,0035x^2 - 0,0216x + 2,9183$. The milk fat content from day 1 to day 21 during storage for the CKS series was $M=2.95$, $SD=0.019\%$.

During storage in the refrigerator, the milk fat content of the CKV kefir was as follows: 1 day $3.00 \pm 0.0049\%$, 7 days $3.00 \pm 0.0191\%$, 14 days $2.75 \pm 0.0746\%$, and 21 days $2.90 \pm 0.0170\%$. The milk fat content from day 1 to day 21 during storage for the functional CKV kefir series was $M=2.916$, $SD=0.029$. The function representing the approximate values for milk fat content is a cubic function, and the same for the production series of CKV kefir is $y = 0.0003x^3 - 0.0102x^2 + 0.0627x + 2.9507$.

During refrigerated storage of the CKP kefir, the milk fat content was: 1 day $3.00 \pm 0.0064\%$, 7 days $3.00 \pm 0.0354\%$, 14 days $2.76 \pm 0.0651\%$, and on the 21st day the milk fat content was $3.00 \pm 0.0537\%$. The average milk fat content from day 1 to day 21 during storage for the functional CKP kefir series was $M=2.941$, $SD=0.040$. The function representing the approximate values for milk fat content is a cubic function, and the same for the functional CKP kefir series is $y = 0,0004x^3 - 0,0111x^2 + 0,0659x + 2,9493$.

Comparative analysis of milk fat content in production series of control and functional kefir during storage is presented in Figure 3. The milk fat content was higher in the control kefir. The results indicate that on the first day of storage, the control kefir had a higher milk fat content.

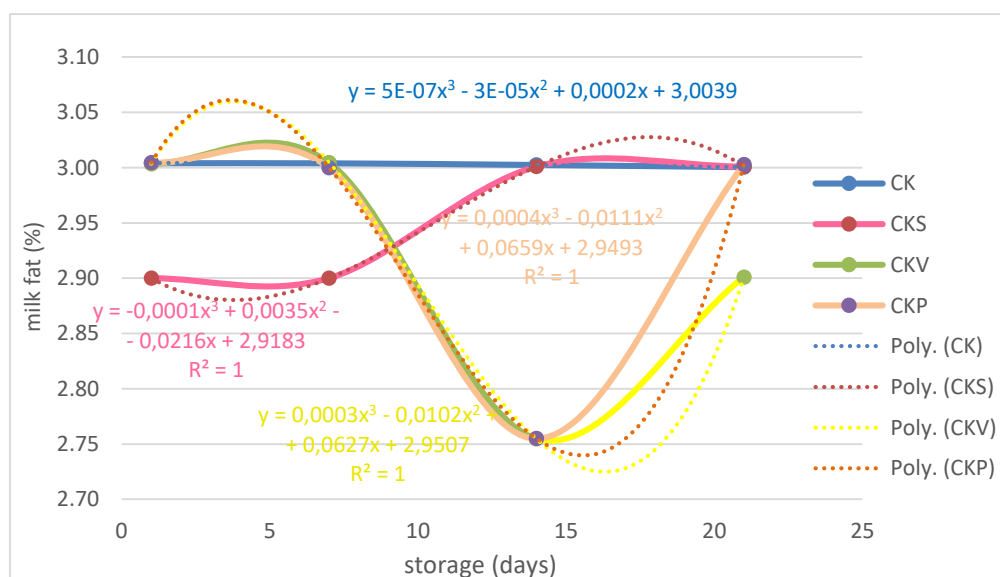


Figure 3: Comparison of the dynamics of milk fat in production batches of control and functional kefir during storage

On the first and seventh days, the CK, CKV, and CKP series had the highest milk fat concentration at 3.00%, while the functional kefir with strawberry had the lowest milk fat content at 2.9%. The addition of vanilla and dietary fiber flavors did not significantly reduce the milk fat content in the functional yogurt series.

The milk fat content in the control and functional yogurts on the 14th day ranged from 2.75% to 3.00%. However, on the 14th day, the highest fat content was observed in CK and CKJ, while it significantly decreased in CKV and CKP. On the last day of storage, a similar percentage of milk fat content was observed in CK, CKS, and CKP at 3.00%, while the vanilla-flavored kefir had a fat content of 2.90%.

The functions representing the dynamics of milk fat content in the functional kefir production series show deviations in fat content during storage, whereas the values for the control kefir series remained relatively constant.

Statistically significant differences in milk fat content were observed in the CK and CKS kefir production series on the first and seventh days: $t(1)=11.18$, $p=0.028$, and $t(1)=20.41$, $p=0.016$. However, on the 14th and 21st days, there were no statistically significant differences: $t(1)=-0.13$, $p=0.458$, and $t(1)=-0.11$, $p=0.465$.

Statistically significant differences in milk fat content were found in the CK and CKV yogurt production series on the first and seventh days of storage: $t(1)=11.18$, $p=0.028$, and $t(1)=20.41$, $p=0.016$. However, on the 14th and 21st days of storage, there were no statistically significant differences: $t(1)=-0.13$, $p=0.458$, and $t(1)=-0.11$, $p=0.465$.

A statistically insignificant difference in milk fat content was observed on the 1st, 7th, and 21st days in the CK and CKP production series: $t(1)=-0.28$, $p=0.413$, $t(1)=0.50$, $p=0.352$, and $t(1)=-0.13$, $p=0.460$. However, on the 14th day, the difference was statistically significant, with $t(1)=8.68$, $p=0.036$.

3.4. Essential minerals in control and functional kefir series

The analyses of the essential mineral content were conducted on the 14th day of storage, as shown in Table 4. The kefirs are characterized by the content of calcium (Ca), zinc (Zn), phosphorus (P), copper (Cu), iron (Fe), magnesium (Mg), potassium (K), sodium (Na), and manganese (Mn).

Table 1 displays the results of the average content of essential minerals and their standard deviations in the control kefir and the three types of functional kefirs. From the results in Table 1, we can conclude that for the control kefir, the order of macro-nutrients by concentration is $K > P > Mg > Ca > Na > Zn > Cu > Fe$, while for the functional kefir with strawberry, the order is $K > Mg > P > Ca > Na > Zn > Cu > Fe$. Additionally, it was found that the macro-element potassium (K) was quantitatively the most prominent in CKV among the analyzed minerals, and the other macro-nutrients followed the sequence $P > Mg > Ca > Na > Zn > Fe > Cu$. In CKP, the order of macro-nutrients was $Mg > K > P > Ca > Na > Mn > Zn > Fe > Cu$.

Table 1: Average content of essential minerals and their standard deviation in the control kefir and the three types of functional kefir

mg/kg	CK	CKS	CKV	CKP
Zn- zinc	26,4 ± 0	24± 0	28,4 ± 0	22,3 ± 0
P - phosphorus	720 ± 99	690± 28,28	732,5 ± 21,21	750 ± 49,49
Cu - copper	0,125 ± 0	0,125± 0	0,01 ± 0	0,01 ± 0
Fe - iron	0,07 ± 0	0,05± 0	0,08 ± 0	0,04 ± 0
Ca - calcium	200,7 ± 124,5	300,7± 56,64	541,3 ± 28,36	401 ± 56,54
Mg-magnesium	693 ± 15,56	850,5± 15,56	644 ± 15,56	1093 ± 43,84
K-potassium	905 ± 50,91	1012± 93,33	918,8 ± 22,63	871,3 ± 50,91
Na - sodium	198,75 ± 8,49	283,75 ± 21,21	260 ± 7,01	333,8 ± 28,28
Mn- manganese	n.f.	n.f.	n.f.	141 ± 0

n.f. - not found presence

During the examination of mineral concentrations in the control and functional kefir with strawberry and vanilla, the presence of manganese (Mn) was not found.

The tested samples using t-tests indicated that most of the results of essential minerals were not statistically significant. When conducting the t-test on the mineral content results from our research, there was no significant difference between the control kefir and the functional kefir CKS. Most elements were present in higher concentrations in the functional kefir production series, but the t-test showed that the results of essential minerals were not statistically significantly different, except for the value of Mg ($p < 0.01$), which showed a high statistical significance. Statistically significant differences were shown for the values of Mg, Ca, and Na in functional kefir CKV compared to control kefir CK, with ($p < 0.05$), and for Mg and Na in CKP compared to CK, with ($p < 0.05$).

Table 2: Statistical significance of essential mineral content differences in kefir compared to the control kefir.

mg/kg	CK-CKS	CK-CKV	CK-CKP
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Zn- zinc	ns	ns	ns
P - phosphorus	ns	ns	ns
Cu - copper	ns	ns	ns
Fe - iron	ns	ns	ns
Ca - calcium	ns	*	ns
Mg-magnesium	**	*	*
K-potassium	ns	ns	ns
Na - sodium	ns	*	*

ns, not statistically significant, *P < 0.05, **P < 0.01, ***P < 0.001

From Table 2, it can be concluded that the addition of flavor and dietary fiber in the functional kefir series did not significantly affect the content of essential minerals.

3.5. Principal Component Analysis (PCA) of essential minerals in kefir

Through Principal Component Analysis (PCA) of the essential minerals, 86.6% of the variability among kefirs is explained (Graph 4). Principal Component 1 consists of the representation of (54.00%) Fe, Zn, K, and Cu. Principal Component 2 is represented by (32.61%) and consists of P, Ca, Mg, Na, Mn. Generally, control and functional kefirs are characterized by a higher representation of Principal Component 2 (P, Ca, Mg, Na).

Regarding the correlation of essential minerals, Zn and Fe have a very strong positive correlation (0.995538), P and Ca, as well as Ca and Na, have a moderate positive correlation, respectively, (0.477282) and (0.463608). Particularly strong negative correlations are present between Fe and Mg, as well as Mg and K (-0.95), but also between Cu and Ca (-0.875241). K and Na have a very weak positive correlation (0.014384).

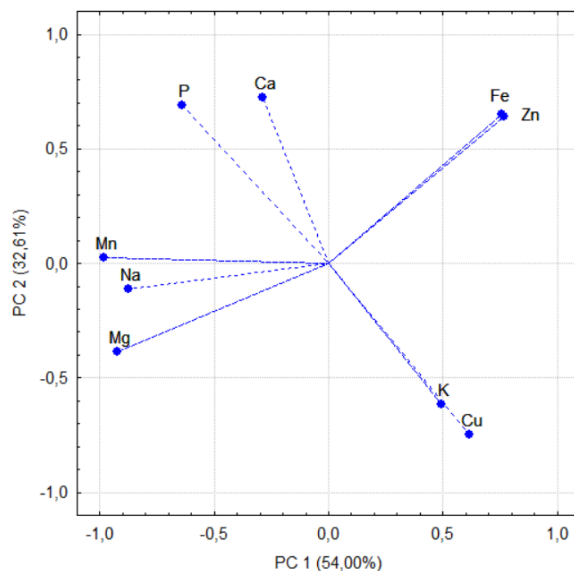


Figure 4: PCA of mineral substances in control and functional kefirs

4. CONCLUSION

In this research, we aimed to explore the nutritional dynamics of functional kefir variants enriched with dietary fiber and flavors compared to classic kefir. Through extensive statistical analyses and comparisons, several significant observations were made.

The protein content in functional kefirs displayed distinct patterns during storage, with variations attributed to flavoring and dietary fiber addition. The functional kefir with vanilla exhibited unique protein dynamics, possibly due to interactions between added components. Dry matter content was influenced by the addition of dietary fiber and flavors, leading to differences in stability between functional and control kefirs. The milk fat content demonstrated variations across different kefir types, reflecting the impact of added ingredients on the overall composition.

Notably, the essential mineral content remained relatively consistent between functional and control kefirs, except for magnesium and sodium, which exhibited minor variations in some cases. Principal Component Analysis highlighted the relationships and variability of essential minerals among the kefir variants.

In conclusion, this study underscores the importance of considering various factors when formulating functional kefir. The addition of dietary fiber and flavors has discernible effects on nutritional content, particularly in terms of protein, dry matter, and milk fat. However, essential mineral composition remains largely unaffected. These insights contribute to the understanding of how functional ingredients can modify the nutritional profile of dairy products, providing valuable information for both consumers and producers in the food industry.

5. ACKNOWLEDGEMENT

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