

ORIGINAL RESEARCH PAPER

INFLUENCE OF AMARANTH (*AMARANTHUS* SPP.) FLOUR ON THE MAIN CHARACTERISTICS OF BUTTER BISCUITS

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Abstract: Butter biscuits contain a large amount of fat to be oxidized during storage. The addition of biologically active substances from various natural sources to butter biscuits improves not only the physico-chemical but also their organoleptic properties. In this study, amaranth flour was used to obtain butter biscuits, in various quantities (5, 10, 15 and 20 %), in order to improve their physicochemical and sensory characteristics. An analysis of a total of 32 features describing changes in the physicochemical, geometric, organoleptic and optical properties of butter biscuits with the addition of amaranth was made. It has been determined that 12.87 % of amaranth flour improves the physicochemical and organoleptic characteristics of butter biscuits. It has been proven that the geometric characteristics, moisture content, active acidity, electrical conductivity, consistency, taste, two-color and one spectral index are sufficiently taken into account in the change in butter biscuits depending on the amount of amaranth flour added. The obtained results can be used to improve suitable and appropriate methods for the analysis of butter biscuits with vegetable additives. Also, the results can be used as preliminary basic data for future evaluations and studies related to the express automated analysis of biscuits. Amaranth flour, due to its special chemical composition and the main content of dietary fiber, can be used to obtain butter biscuits with functional properties.

Keywords: *baking, principal component analysis, products, regression analysis, sensory characteristics*

INTRODUCTION

Biscuits are consumed products because they have a relatively long shelf life and nutritional value. Biscuits are a range of confectionery products characterized by a crunchy texture. In their preparation, aromatic products of plant origin can be added, both in the dough and as a sprinkling of the product. Confectionery biscuits obtained from crumbly butter confectionery base are characterized by some specific organoleptic and physicochemical parameters. They have a pleasant, characteristic taste of the fat used and a crumbly and brittle structure due to the high fat content. With the increase of the crystal sugar used in the recipe, their crumbliness decreases, at the expense of their hardness and their crunchiness. They are preferred by confectionery consumers due to their very good taste, crumbly and crunchy structure and relatively long shelf life of up to 4 months. As a disadvantage may be noted the fact that biscuits have a high gas permeability, which is a precondition for their taste and aroma. In addition, they absorb moisture, which degrades the texture of the baked product [1]. Amaranth (*Amaranthus* spp.) and the flour obtained from this plant have high biological qualities and nutritional properties, which in turn is a suitable ingredient for enriching a variety of confectionery products, including those made from crumbly buttery confectionery base, giving the product a functional character. In recent years, as an additive in biscuits, amaranth is becoming increasingly popular. It is rich in protein, fat and fiber.

Sindhuja *et al.* [2], investigated the influence of amaranth flour on the quality characteristics of biscuits. The plant is added in a modified form in quantities of 0 - 35 %. The authors found that increasing the amount of amaranth flour reduces the water holding capacity of biscuits. The characteristics of the dough also deteriorate. It also reduces the viscosity of the dough. On the other hand, the color of the biscuits improves and branches from pale cream to golden brown. According to the authors, 25 % is the optimal amount of amaranth in biscuits, which improves the characteristics of the dough and the final product – biscuits.

Grobelnik *et al.* [3], investigated the effect of 0 - 30 % addition of whole meal amaranth flour on the main characteristics of biscuit dough. The authors found that increasing the amount of amaranth flour in the dough leads to an increase in gelatinization temperature, water retention and stability. On the other hand, higher levels of amaranth flour lead to softening of the dough. As a result of this study, the authors point out that the addition of 10 - 20 % amaranth flour improves the rheological characteristics of the dough.

After a literature review, Topuzova *et al.* [4], found that amaranth flour has a higher protein content than cereals. The amino acid composition of the flour is balanced and contains a significant amount of essential amino acids. In addition, the plant is a rich source of dietary fiber. The fat content is 2 - 3 times higher than that of cereals.

Inglett *et al.* [5], make a comparative analysis of wheat flour biscuits and those with the addition of amaranth flour added in an amount of 15 %. The authors point out that the viscosity of amaranth dough is higher than that of wheat flour dough. In the case of biscuits with added amaranth, the coefficient of extensibility is higher than that of wheat. Also, their water holding capacity increases.

Karki *et al.* [6], investigated the effect of amaranth flour in quantities of 0 - 50 %. The authors point out that up to 20 % of amaranth flour does not significantly affect the organoleptic characteristics of biscuits made with wheat flour.

Chauhan *et al.* [7], significantly expanded the scope of research by preparing biscuits from wheat flour and 0 - 100 % amaranth. The authors point out that the hardness of biscuits decreases with increasing amount of amaranth. On the other hand, the coefficient of extensibility increases. Biscuits with up to 60 % amaranth are acceptable for consumers. Over 60 % addition of amaranth flour impairs the organoleptic characteristics of biscuits.

Raihan *et al.* [8], investigated the addition of amaranth flour in quantities of 0 - 25 %. The authors found that in quantities of 10 %, the resulting biscuits have acceptable organoleptic characteristics. The addition of more than 10 % amaranth flour reduces the resistance of biscuits to breakage and also increases their spread factor.

Liu *et al.* [9] make a comparative analysis of biscuits prepared with 100 % wheat flour and 100 % amaranth flour. The water holding capacity of amaranth biscuits is higher than those with wheat flour. Also, the viscosity of amaranth biscuits is higher. The expansion factor is higher for wheat flour biscuits. The hardness of the dough is higher with amaranth biscuits, but their fragility is also higher and easier to break. The humidity of amaranth biscuits is higher than that of wheat flour biscuits. Consumer organoleptic evaluation shows that wheat flour biscuits are acceptable to consumers, and to a much lesser extent 100 % amaranth flour biscuits. Similar results were reported by Sabbione *et al.* [10]. The authors analyzed biscuits made from 100 % amaranth flour. Comparing amaranth flour, dough and biscuits, they found that the protein in flour is twice as much as in dough and ready-made biscuits. The same trend is observed for the content of ash and fiber. The three products have the same amount of carbohydrates.

Man *et al.* [11], investigated the characteristics of biscuits with the addition of 0 - 100 % amaranth flour. According to the authors, the changes in the color of the biscuits, as well as their nutty taste, bitter aftertaste, which are the result of the addition of amaranth flour, are most significant over 50 % of the additive. This has a negative effect on the texture, color, taste and aroma of the final product. To maintain the same quality of the product, amaranth flour should be added up to 50 %.

Saeid *et al.* [12] review research on the use of amaranth in biscuits. The authors confirm the high protein content in amaranth flour, reaching levels of 10 - 14 %. In addition to high enough 10 % starch, the plant is rich in flavonoids and tocotrieneols. It is a rich source of the minerals magnesium, potassium, zinc, phosphorus. Compared to wheat flour biscuits, those with amaranth flour, have higher coefficient of expansion. This coefficient decreases significantly with the addition of 10 - 20 % amaranth. The thickness of the cookie increases, up to 20 % add amaranth flour. Consumer organoleptic evaluations show that biscuits, with a maximum of 40 % amaranth flour, have the best characteristics.

A review of the available literature shows that research into the use of amaranth as an ingredient in biscuits shows that the addition of more than 50 % amaranth flour degrades the quality characteristics of the product. Permissible levels of amaranth flour content have also been reported in a wide range of 10 - 40 %. Research is related to the addition of plant flour in biscuits, cakes, bread. No studies have been found on the use of amaranth flour as an additive in butter biscuits.

Modern research is increasingly focused on the development of confectionery products with increased nutritional and biological value. Research on the use of amaranth flour in butter biscuits is becoming more and more relevant.

The wide range of the amount of amaranth flour used as an additive. The wide range of permissible amounts of the product in biscuits does not give a clear idea of how much amaranth can be added to butter biscuits. For this purpose, it is necessary to use computer-based algorithms to specify the allowable amount of amaranth in butter biscuits.

Methods for computer-based statistical analysis, with volume reduction, have been applied to biscuits with food waste [13]. These analyzes are related to the correlation between different characteristics of biscuits, as well as the representation of these characteristics after their reduction with the method Analysis of the main components [14]. The methods of reducing the volume of data on trait vectors have also been applied in the search for a link between organoleptic evaluation and physicochemical parameters of biscuits [15]. Regression analysis is also addressed in modern biscuit research [16]. Relationships have been sought between the basic, easily measurable characteristics of biscuits and their chemical composition, usually determined by methods such as gas chromatography. The optimal ratio of functional additives in biscuits has been determined [17].

Insufficient research has been found on the use of these computer-based statistical methods to determine the optimal amount of additional raw materials in butter biscuits. In the case of biscuits with the addition of amaranth flour, no application of such complex statistical methods has been found. The use of such methods to determine the appropriate amount of amaranth in butter biscuits is the aim of the present work.

MATERIAL AND METHODS

Amaranth flour from India (Jeev Organo India Opc Private Ltd., Delhi, India) was used. The flour is packaged in Bulgaria (New S Net, Ltd., Sofia, Bulgaria). White wheat flour type 500 (Topaz Mel, Ltd., Sofia, Bulgaria) was used to make biscuits. Powdered sugar (Agrana trading Ltd., Sofia, Bulgaria). Sayana butter (Milky group Ltd., Haskovo, Bulgaria). Chicken eggs (according to the EU Ordinance № 1 of 9 January 2008 on the requirements for the marketing of table eggs, which determines the necessary requirements for delivery, storage, transport, grading, marking and packaging of eggs intended as food for consumers, including the procedure for carrying out related inspections and mandatory checks). Liquid fragrance (Dr. Oetker, Bielefeld, Germany), that according to the manufacturer does not contain ingredients that may cause allergic reactions or other intolerances. Table 1 shows the composition of the white wheat flour type 500, amaranth flour and butter, according to the manufacturers data.

Table 1. Composition of raw materials g/100 g

Composition	White wheat flour type 500	Amaranth flour	Butter "Sayana"
Energy [kcal/kJ]	351	376	743
Fats [g/100 g]	0.9	7.2	82
Proteins [g/100 g]	10.47	18.4	0.7
Carbohydrates [g/100 g]	74.03	65.25	0.6
Fibers [g/100 g]	No data	6.7	No data
Sugars [g/100 g]	11.15	No data	0.6
Salt [g/100 g]	No data	0	1.5

Preparation of the butter biscuits

Amaranth flour was added in amounts of 5, 10, 15 and 20 % to the main recipe of butter biscuits. Table 2 shows the recipe and composition of the samples of amaranth biscuits. The amount of wheat flour and that of amaranth is changed, while the quantities of other raw materials are preserved. No water was used in the preparation of the biscuits.

Table 2. *Quantities of raw materials*

Raw material [kg] \ Amaranth [%]	0	5	10	15	20
Wheat flour	0.179	0.170	0.161	0.152	0.143
Powdered sugar	0.089	0.089	0.089	0.089	0.089
Unsalted cow butter	0.149	0.149	0.149	0.149	0.149
Whole hen eggs	0.014	0.014	0.014	0.014	0.014
Liquid fragrance	0.001	0.001	0.001	0.001	0.001
Amaranth flour	0.000	0.009	0.018	0.027	0.036

Table 3 shows the technology for making butter biscuits with the addition of amaranth flour. It consists of 11 stages. Some of the technological operations are performed at room temperature, and those in which the softening of the butter should be avoided are at lower than room temperature. The total time for preparing the biscuits according to the presented technology is 2.5 - 3 hours.

Table 3. *Technological methodology for preparation of confectionery crumbly butter biscuits with amaranth flour*

Stage	Time [min]	Temperature [°C]	Name	Description
1	-	20-22	Preliminary preparation of raw materials	Sifting the flour, disinfecting the hen eggs
2	-	20-22	Dosing of raw materials	According to the recipe presented above
3	5-10	18-20	Preparation of crumbly butter confectionery base for obtaining shaped confectionery biscuits (dough)	Mix wheat flour, enrichment component, powdered sugar, butter, beaten whole hen eggs and flavoring. The machining is short-lived to avoid softening of the butter
4	30-40	3-4	Cooling	Cool the semi-finished dough in refrigerated conditions
5	-	18-20	Cooling	Sheet thickness of dough 5-8 mm
6	-	18-20	Rolling	By cutting shapes from rato dough, with a cutter, of a certain size
7	-	18-20	Formation	Pre-prepared baking trays
8	10-12	200	Arrange in baking trays	In convective firing mode
9	60	20-22	Baking	Under room conditions
10	-	20-22	Cooling	In plastic bags
11	-	20-22	Packaging	In the dark, without access to direct sunlight and sources of moisture and odors

Thermal losses after baking

After baking, the biscuit samples were cooled to room temperature and weighed on a technical balance to the nearest 0.1 g. Thermal losses (TL , %) are determined by the following formula, presented by equation 1:

$$TL = \frac{a - b}{a} \times 100 [\%] \quad (1)$$

where a - mass of the sample before baking, g;

b - mass of the sample after baking, g.

A technical scale Boeco BBL-64 (Boeckel GmbH, Hamburg, Germany) was used, with a maximum capacity of 300 g and an accuracy of 0.1 g.

Spread factor

After baking the biscuits, diameter (D , mm) and height (h , mm) were measured. The biscuit was measured on three sides and the average value of its diameter was taken. In the same way, its height was measured at three points. An electronic digital caliper SEB-DC-023 (Shanghai Shangerbo Import & Export Co., Ltd., Shanghai, PR China) was used, with an accuracy of 0.05 mm and a maximum measured length of 150 mm. The spread factor (SF) is determined by the following formula, presented by equation 2:

$$SF = \frac{D}{h} \quad (2)$$

where D is the diameter of the biscuit after baking, mm;

h - height of the biscuit after baking, mm.

Moisture content

The moisture content (MC, %) was determined with a Kern DBS 60-3 dehumidifier (KERN & SOHN GmbH, Balingen, Germany). The prepared 5 g sample was dried until its mass was constant.

Determination of pH, EC, TDS and ORP

The preparation of the samples for measurement was made according to the method according to AACC 02-52.01 Hydrogen-Ion Activity (pH) - Electrometric Method (method for determining the activity of hydrogen ions (pH) of flour and some bakery and confectionery products such as bread, crackers, cakes and biscuits which do not emit gases and change their pH when suspended in water. The method cannot be used in dough analysis). According to the instructions for use of this method, distilled water is heated to 70 °C; the raw material is dissolved in distilled water in a ratio of 1/10 (5 g of raw material in 50 mL of distilled water); stirring until a homogeneous solution is obtained; after cooling to ambient temperature in the room, 3 consecutive measurements of each characteristic were made and their average value and standard deviation were determined. The quantity of raw materials is determined with a technical scale Pocket Scale MH-200 (ZheZhong Weighing Apparatus Factory, Yongkang City, Zhejiang Province, PR China), maximum specified weight 200 g, with a resolution of 0.02 g. Electrical conductivity (EC, $\mu S \cdot cm^{-1}$) was determined with a Conductivity Meter AP-2 (HM Digital, Inc., Culver City, CA).

For the active acidity (pH) we used the pH meter PH-108 (Hangzhou Lohand Biological Co., Ltd) and for the total dissolved solids (TDS, ppm), a TDS-3 measuring instrument (HM Digital, Inc., Culver City, CA) and for the temperature measuring a digital thermometer, V&A VA6502 (Shanghai Vihua V&A instrument CO, Ltd., Shanghai, PR China).

Oxidation-reduction potential (ORP, mV) was determined with a Measuring Instrument Model ORP-2069 (Shanghai Longway Optical Instruments Co., Ltd., Shanghai, PR China).

Organoleptic evaluation

The organoleptic consumer assessment was made by 52 persons from Yambol, Bulgaria. Appearance, texture, aroma, taste, smell, chewiness of the biscuits were evaluated. A 5-point Linkert scale was used (1-strongly disagree; 5-strongly agree). A questionnaire was compiled, presented in Figure 1. The card is attractive to the consumers. An evaluation table has been made on it, a brief instruction on the importance and evaluation of the characteristics of the product has been introduced. The questionnaire is maximally synthesized and summarized, because the respondents would not like to fill in a questionnaire with many questions or have to read instructions with a large volume. After a brief briefing, respondents proceeded to evaluate butter biscuits with different percentages of amaranth.

Assessment scale							
Value	5	4	3	2	1		
decision	Strongly agree	Agree	No decision	Disagree	Strongly disagree		
Consumer assessment							
Criterion	Appearance	Consistency	Aroma	Taste	Smell	Chewiness	
Amaranth content [%]							
0							
5							
10							
15							
20							

Appearance. The condition of the surface is not rough and there are no cracks.
Consistency. It is not hard, brittle, it is soft, there is no crunch (does it feel unbroken raw material).
Aroma. It has a specific and characteristic aroma of butter.
Taste. It is sweet, it is pleasant, it is typical for a butter biscuit, it has no side taste.
Smell. There is no an uncharacteristic smell of butter biscuit.
Chewiness. When biting, there is no feeling of smearing, sticking on the teeth.

Figure 1. Consumer assessment card

Obtaining color digital images

A video sensor of a LG L70 mobile phone (LG Electronics, Inc., Seoul, Korea) was used. The video sensor is VB6955CM (STMicroelectronics International N.V., Geneva, Switzerland). 2600x1952 pix resolution. Pixel size 1.4x1.4 μm .

Method for selection of informative features

A method for ranking significant characteristics to create regression models, RReliefF [18], was used. The algorithm is applicable when assessing the informativeness of features used for distance-based models.

Color components

Color digital images in RGB color model were obtained, which were converted to Lab and LCh according to CIE 1976 color models. Functions were used to convert color components at 2° observer and D65 illuminance (average daylight with UV component, 6500 K).

The color components of the RGB (RGB [0 255]) model were converted to Lab (L [0 100], a [-86.18 98.23], b [-107.86 94.47]).

When converting Lab to LCh, $L(\text{Lab})=L(\text{LCh})$. The other color components (C and h) are converted according to the following formulas, presented by equation 3:

$$C = \sqrt{a^2 + b^2} \quad h^\circ = \text{atan}\left(\frac{b}{a}\right) \quad (3)$$

Color difference

The color difference ΔE is determined, with the formula, presented by equation 4. It varies in the range 0-100, as the closer it is to 0, the closer the colors of the amaranth biscuits are to those of the control sample, and the closer to 100, the more different they are.

$$\Delta E = \sqrt{(L_c - L_a)^2 + (a_c - a_a)^2 + (b_c - b_a)^2} \quad (4)$$

where L_c , a_c , b_c are the color components of the control sample; L_a , a_a , b_a - color components of the sample with the addition of amaranth.

Color indices

The obtained values of the color components are used in the calculation of color indices (CI_x). The indices are determined by the formulas summarized by Pathare *et al.* [19]. The RReliefF method selects such color indices that sufficiently reflect the changes in the biscuits with the addition of amaranth. A total of six indices were selected in the paper. The following mathematical formulas were used to determine them, presented in equations 5 - 10:

$$CI_1 = \frac{142,86b}{L} \quad (5)$$

$$CI_2 = 100 - \sqrt{(100 - L)^2 + a^2 + b^2} \quad (6)$$

$$CI_3 = \sqrt{a^2 + b^2} \quad (7)$$

$$CI_4 = \frac{180 - h}{L + C} \quad (8)$$

$$CI_5 = L - b \quad (9)$$

$$CI_6 = \frac{1000a}{L + h} \quad (10)$$

Spectral characteristics

The conversion of values from XYZ and LMS models into reflection spectra in the VIS region, in the range 390 - 730 nm was done by mathematical formulas presented by Vilaseca *et al.* [20]. These formulas are for observer 2° and illumination D65 (average

daylight with UV component (6500K)). The conversion to spectral characteristics in the VIS domain (R_{VIS}) is based on the presented dependencies by equations 11 - 14:

$$XYZ = RGB \cdot M_{XYZ} \quad (11)$$

$$LMS = XYZ \cdot M_{LMS} \quad (12)$$

$$L = \int_{380}^{780} A(\lambda) \bar{L}(\lambda) d\lambda; M = \int_{380}^{780} A(\lambda) \bar{M}(\lambda) d\lambda; S = \int_{380}^{780} A(\lambda) \bar{S}(\lambda) d\lambda \quad (13)$$

$$R_{VIS} = \sqrt{\Delta L^2 + \Delta M^2 + \Delta S^2} \quad (14)$$

where M_{XYZ} and M_{LMS} are matrices for conversion between color models, for the above observer and illuminance. The conversion from XYZ to LMS color model is according to [21]. $A(\lambda)$ is a matrix for converting to the spectra of reflection in the visible region, for the above observer and illuminance. Matrices are available in [22]. Spectral indices (SI_x) are determined according to Cermakova *et al.* [23] and Atanassova *et al.* [24]. The RReliefF method selected spectral indices that sufficiently reflect the changes in the biscuits with the addition of amaranth. The following mathematical formulas were used to determine them, presented by equations 15 - 19:

$$SI_1 = \frac{R_{740}}{R_{720}} \quad (15)$$

$$SI_2 = \frac{R_{530} - R_{570}}{R_{530} + R_{570}} \quad (16)$$

$$SI_3 = \frac{1}{R_{510}} - \frac{1}{R_{550}} \quad (17)$$

$$SI_4 = 0,5(120(R_{750} - R_{550}) - 200(R_{670} - R_{550})) \quad (18)$$

$$SI_5 = \frac{R_{550}}{R_{680}} \quad (19)$$

Formation of a feature vector

This vector includes physico-chemical, organoleptic characteristics of the product, color and spectral indices of butter biscuits with the addition of amaranth. The formed vector of a total of 32 features is shown in Table 4.

Table 4. Features that describe the changes of butter biscuits with amaranth

Feature	Meaning	Feature	Meaning	Feature	Meaning
F1	TL [%]	F12	Aroma	F23	CI ₂
F2	D [mm]	F13	Taste	F24	CI ₃
F3	h [mm]	F14	Odor	F25	CI ₄
F4	SF	F15	Chewiness	F26	CI ₅
F5	MC [%]	F16	Overall evaluation	F27	CI ₆
F6	pH	F17	L	F28	SI ₁
F7	EC [$\mu\text{S} \cdot \text{cm}^{-1}$]	F18	a	F29	SI ₂
F8	TDS [ppm]	F19	b	F30	SI ₃
F9	ORP [mV]	F20	C	F31	SI ₄
F10	General appearance	F21	h	F32	SI ₅
F11	Consistency	F22	CI ₁	-	-

From the thus formed feature vector, by the RReliefF method, a group of informative features was selected, which reflect the changes in the biscuits after the addition of amaranth, and also have a low correlation with each other.

Method for reducing the volume of data in a feature vector

The principal components analysis (PCA) [25], creates an orthogonal coordinate system, depending on the variance in the original data, the axes are arranged according to the respective principal component and the variances in the master data. In the covariance matrix of the data, as presented by equation 20:

$$K = E[(x - \bar{x})^T(x - \bar{x})] \quad (20)$$

where x is an input variable, their variations can be seen. If the matrix is diagonal, the variables are independent and in this case the data can be visualized by their root mean square error by selecting the ones with the largest variance. If it is not diagonal, the matrix can be transformed to one containing its own vectors as the main diagonal.

Also, the PCA method was used to determine which of the characteristics of butter biscuits is affected by the addition of amaranth flour. Table 5 presents the feature-quantity combinations of amaranth. Prior to PCA treatment, the data in the table are normalized in the range [0; 1].

Table 5. *Feature/ Amaranth combinations table*

Feature Amaranth [%]	F1	F2	...	Fm
A0	A0F1	A0F2	...	A0Fm
A5	A5F1	A5F2	...	A5Fm
...
An	AnF1	AnF2	...	AnFm

Regression model

A regression model, mainly used for food analysis was used in the present work [18]. It describes the relationship between both independent and dependent variables and has the form, as presented in equation 21:

$$z = b_0 + b_1x + b_2y + b_3x^2 + b_4xy + b_5y^2 \quad (21)$$

where x and y are independent variables; z - dependent variable; b - coefficients of the model.

The coefficient of determination (R^2), the coefficients of the model, their standard error (SE), t-statistics (tStat), p-value, Fisher's test (F) were used to evaluate the model. A residual analysis was performed.

The coefficients of the model and their standard error are determined, and each of them is analyzed depending on the value of the p-level compared to the level of significance α . Non-informative coefficients with $p > \alpha$ were rejected. The significance of the coefficients is determined by Student's criterion, and the adequacy - by Fisher's criterion. Stat Soft Statistica 12 (TIBCO Software Inc., Palo Alto, CA, USA) was used to create this regression model.

The ANOVA method is applied to access the statistical difference between groups of samples, with the Statistica 12 software.

Linear programming algorithm

A linear programming algorithm implemented using the *linprog* function in the Matlab software system (The Mathworks Inc., Natick, MA, USA) was used to determine the appropriate amount of basil. Linear programming is the solution of the problem of finding a vector x such that the linear function $f^T x$, with linear constraints, presented in equation 22:

$$\min_x f^T x \quad (22)$$

to be fulfilled under one of the conditions, presented in equation 23:

$$Ax \leq b \quad A_{eq}x = b_{eq} \quad l \leq x \leq u \quad (23)$$

An "Interior-point-legacy" function was used. The function arrives at an appropriate solution by traversing the inside of the data area [26].

All data were processed at a level of significance $\alpha=0.05$.

RESULTS AND DISCUSSION

Figure 2 shows in general view the change in the surface characteristics of butter biscuits with added different percentage of amaranth flour. As the amount of amaranth flour increases, it can be seen that both the color characteristics and the surface structure of the product change.

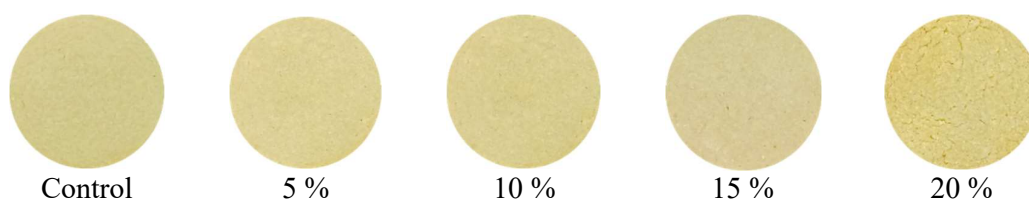


Figure 2. Biscuits with/without amaranth flour – general view

Figure 3 shows the results of determining thermal losses. The highest values of thermal losses are observed in the control sample and the one with 20 % amaranth, compared to the other samples. Increasing the amount of amaranth to 15 % leads to a reduction in thermal losses, after which it begins to grow again. This is probably due to the change in the concentration of amaranth in the biscuits.

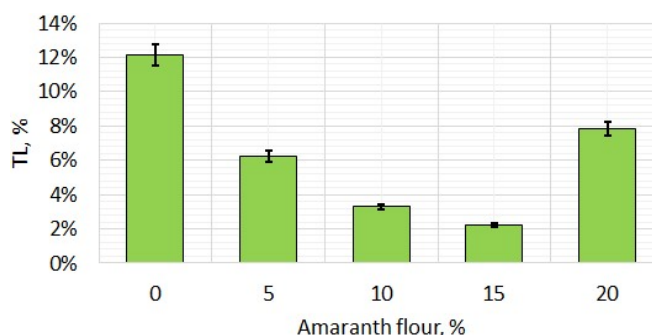


Figure 3. Thermal losses of butter biscuits with amaranth flour

The values are significantly different at $p<0.05$

Table 6 shows data on the change in the geometric characteristics of the biscuits. The height of biscuits was decreased by increasing amaranth content. The values of the spread factor are also indicated. Increasing the amount of amaranth leads to an increase in the diameter of the biscuits, but also to an increase in their height. This trend is observed at the spread factor, which is the highest value in the sample with 5 % amaranth. When the amount of amaranth increases to 15 %, the values of the coefficient decrease, after which its increase is observed again. The increased value of the spread factor is due to changes in the rheological properties of the unbaked and baked product [2]. This is most likely due to the weakening effect of the dietary fiber imported with amaranth flour, which is insoluble in the rheological properties of the dough.

Table 6. The geometry properties of butter cookies with amaranth

Dimensions Amarnath [%]	D [mm]		h [mm]		Spread factor SF (D/h)
	Before backing	After backing	Before backing	After backing	
0	60	64.15±1.52	5	7.87±1.53	8.15±1
5	60	66.27±3.96	5	6.95±0.73	9.54±5.4
10	60	65.72±2.4	5	7.89±1.1	8.33±2.17
15	60	67.99±2.75	5	7.48±0.15	9.09±18.27
20	60	69.46±1.25	5	7.48±0.02	9.29±59.84

Mean±SD; n=3; The values are significantly different at $p<0.05$

Figure 4 shows the results of determining the moisture content. In this case, there is a clear tendency to reduce the moisture content in the biscuits with increasing the amount of amaranth. Relatively equal values of humidity are observed at close amounts of amaranth added to the biscuits. For example, 5% and 10% are close in humidity, as well as 15 % and 20 %. The moisture content of the biscuits decreases because the higher amaranth flour affects the moisture content of the total mixture of wheat flour type 500 and amaranth flour, and this also affects the moisture content of the final baked product.

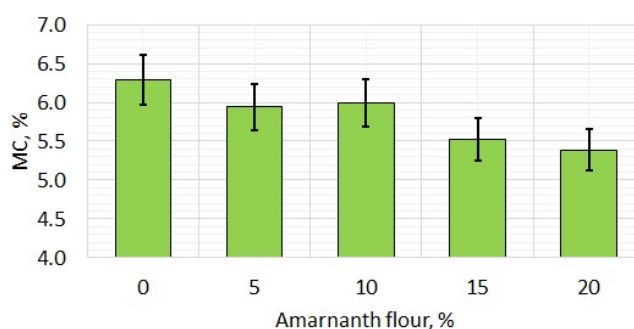


Figure 4. Moisture content (MC [%]) of butter biscuits with amaranth

The values are significantly different at $p<0.05$

Table 7 shows the measured values of pH, EC, TDS and ORP of the biscuits with added amaranth flour. The values of active acidity remain relatively constant, regardless of the amount of amaranth added. The values of electrical conductivity increase up to 10 % of the addition of amaranth, then decrease and at 20 % reach the levels of the control sample. The same trend is observed for totally dissolved solids. With an increase in the percentage of amaranth, the values of the oxidation-reduction potential show a clear downward trend. The active acidity remains relatively constant due to the good

buffering capacity of milk fat and milk proteins imported with butter. Changes in electrical conductivity and total dry soluble substances are due to the specific composition of amaranth flour, as it is rich in antioxidants of polyphenolic nature and substances with antimicrobial activity, having in their chemical structure a significant number of hydroxyl groups that are able to form in aqueous phase weak hydrogen bonds with water molecules, which is a prerequisite for the impact on these indicator [3]. According to the results obtained for the redox potential, it can be considered that the resulting product accumulates significant amounts of reducing substances imported with the enriching raw material or obtained during heat treatment.

Table 7. pH, EC, TDS and ORP of butter biscuits with amaranth

Characteristic Amaranth flour [%]	pH	EC [$\mu\text{S}\cdot\text{cm}^{-1}$]	TDS [ppm]	ORP [mV]
0	7.4±0.3	525±59.6	249±61.4	207±21.2
5	7.5±0.1	536.5±93.2	254.5±64.9	203±17
10	7.5±0.1	522.5±69.1	255.5±43.5	199.5±13.4
15	7.5±0.1	515.5±33.2	250±64.2	196±11.3
20	7.4±0.1	495.5±42.1	249±77.1	192±18.5

The values are significantly different at $p < 0.05$

Table 8 shows the results of the organoleptic evaluation of butter biscuits with the addition of amaranth. As the amount of amaranth in the biscuits increases, more and more pronounced pores appear on their surface. This can be seen from the consumer assessment of this indicator. At higher rates of amaranth, consumers rate biscuits lower. Regardless of the added amount of amaranth, the taste and smell of butter biscuits are preserved at high levels. This is indicative that the additive does not significantly affect these characteristics of butter biscuits. The odor has low values of organoleptic evaluation. Chewing values decrease with increasing amount of amaranth. This is because higher amounts of the additive increase the hardness of the biscuits. The overall evaluation of the biscuits shows that up to 10 % additive, they are well accepted by consumers, with increasing amount of amaranth, decreases the overall evaluation of the product, which is related to the specific taste preferences of the consumer.

Table 8. Sensory evaluation of butter cookies with amaranth

Characteristic Amaranth [%]	0	5	10	15	20
General appearance	4.63±0.52	4.63±0.52	4.25±0.71	3.75±1.28	3.63±1.19
Consistency	4.5±0.53	4.25±0.71	4.25±0.89	3.25±1.16	3.13±1.25
Aroma	4.75±0.46	4.75±0.46	4.38±0.74	4.5±0.76	4.13±0.83
Taste	4.88±0.35	4.75±0.46	4.5±0.53	4.25±0.46	4.5±0.76
Smell	2.88±1.64	2.88±1.64	3.13±1.64	3±1.51	2.38±1.51
Chewiness	4±1.31	3.88±0.99	3.5±1.2	3.25±1.04	3.63±1.3
Overall evaluation	4.27±0.8	4.19±0.8	4±0.95	3.67±1.04	3.56±1.14

The values are significantly different at $p < 0.05$

Table 9 shows the values of the Lab color components of biscuits with the addition of amaranth. Increasing the amount of amaranth leads to an increase in the values of the L-component. The values of the b-component increase, while those of the a-component decrease. The color changes from darker yellow-brown to lighter levels of this color.

There is less variation in color ranges. The processes of melanoidin formation, non-enzymatic browning and caramelization, which take place during the baking of the biscuits, have an additional influence on the color characteristics of the baked biscuits [4]. They also affect the color characteristics to the darker yellow-brown color gamuts. Figure 5 shows the color difference between the biscuits with different percentage of amaranth and the control sample. As can be seen from the graph, an increase in the color difference compared to the control sample of up to 15 % amaranth supplementation was observed. At 20 % addition, the difference is again low.

Table 9. Lab color values of butter cookies with amaranth

Amaranth [%] Color values	0	5	10	15	20
L	79.81±1.68	83.72±1.04	81.24±0.64	82.37±0.64	81.05±1.51
a	-5.63±1.63	-4.51±0.8	-5.2±0.58	-4.69±0.82	-4.1±0.67
b	35.01±4.63	31.12±2.52	27.62±1.62	26.12±1.39	40.01±3.64

The values are significantly different at $p < 0.05$

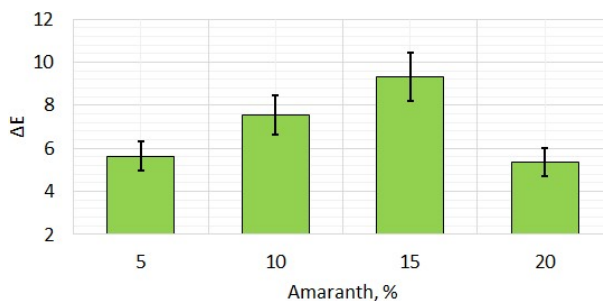


Figure 5. Color difference between control sample and amaranth enriched biscuits

The values are significantly different at $p < 0.05$

Figure 6 shows the spectral characteristics of butter biscuits with the addition of amaranth.

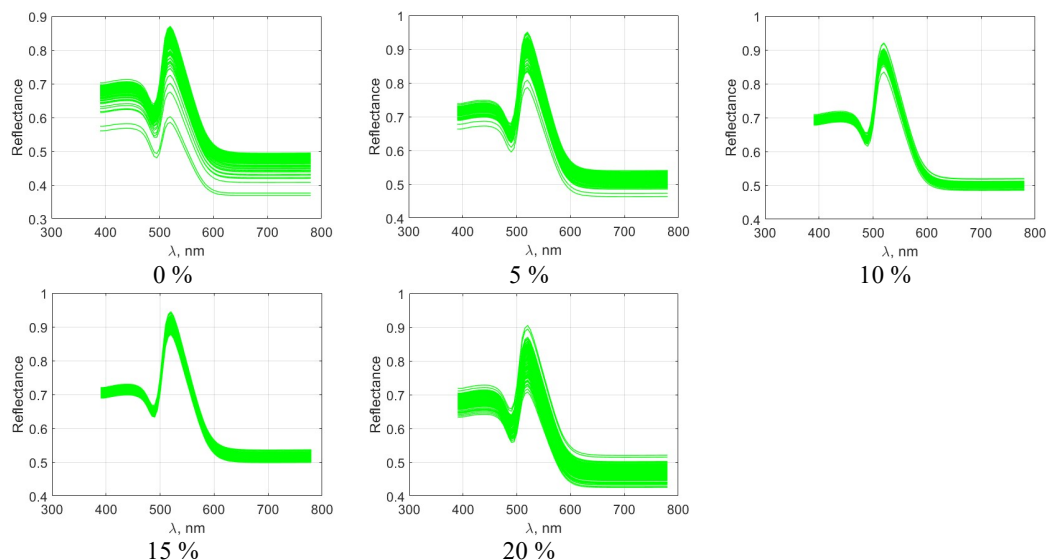


Figure 6. Spectral characteristics of butter cookies with amaranth

The lowest values of reflection are observed in the control sample. Increasing the amount of amaranth results in higher reflection levels compared to the control sample, but it is relatively the same for all samples with this additive. It can also be seen that with 5 - 15 % additive the characteristics are close to each other. With a larger amount of amaranth, due to the appearance of hanging cracks on the surface, the reflection spectra change in a wider range compared to other samples [2].

A selection of informative features has been made. The RReliefF method was used. Figure 7 shows the results of this selection. Such features are selected that have a weighting factor greater than 0.6. They are considered informative and reflect to the highest degree the changes in the characteristics of the biscuits, depending on the added quantities of amaranth.

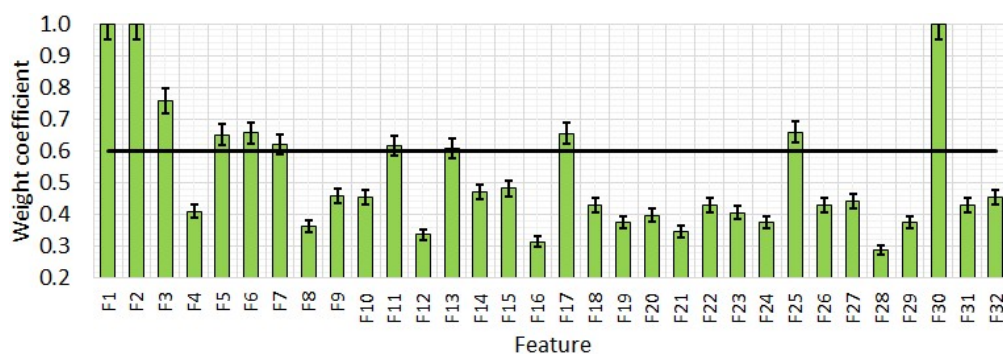


Figure 7. Results from feature selection

The values are significantly different at $p < 0.05$

A vector of a total of 11 informative features was obtained, which describe the changes in butter biscuits with the addition of amaranth. Thermal losses and geometric dimensions of the biscuits were chosen as informative. Moisture content is also an informative feature, the active acidity and electrical conductivity of the physicochemical indicators are significant. Two of the organoleptic characteristics are informative - the texture and taste of the biscuits. One color component, one color and one spectral index, reflect the changes in the biscuits when the percentage of amaranth in the butter biscuits changes.

The vector has the form, presented in equation 24:

$$FV = [F1 \ F2 \ F3 \ F5 \ F6 \ F7 \ F11 \ F13 \ F17 \ F25 \ F30] \quad (24)$$

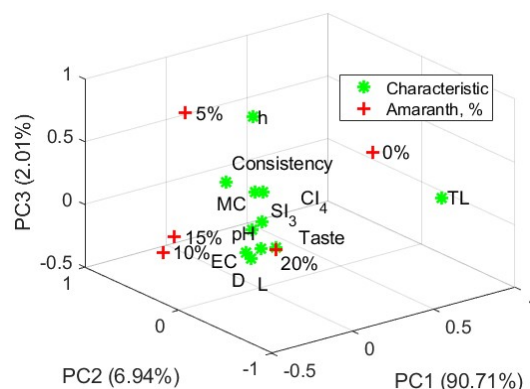
Table 10 shows the values of the characteristics normalized in the interval [0; 1], which are most influenced by the change in the amaranth content in butter biscuits. The number of rows is 5 and the number of columns is 11. This shows that the data can be represented by 4 principal components per row and 10 by columns. The number of principal components required is determined according to the condition that the sum of the principal components must describe more than 95 % of the variance in the data.

The first three principal components describe a total of over 95 % of the variance in the data. The results are shown in Figure 8. The graph of the first three principal components of the standardized characteristics of biscuits is shown.

Table 10. Normed value of biscuit characteristics

Feature	F1	F2	F3	F5	F6	F7	F11	F13	F17	F25	F30
Characteristic Amaranth [%]	TL	D [mm]	h [mm]	MC	pH	EC [$\mu\text{S}\cdot\text{cm}^{-1}$]	Consistency	Taste	L	Cl ₄	Sl ₃
0	0.83	0.00	0.10	0.14	0.00	0.05	0.30	0.12	0.00	0.04	0.01
5	0.33	0.04	0.00	0.09	0.02	0.08	0.24	0.10	0.05	0.00	0.00
10	0.09	0.03	0.12	0.10	0.02	0.05	0.25	0.04	0.02	0.03	0.00
15	0.00	0.05	0.06	0.02	0.02	0.05	0.04	0.00	0.03	0.02	0.00
20	0.08	0.08	0.06	0.00	0.00	0.00	0.00	0.05	0.01	0.02	0.00

As can be seen from the graph, the addition of 5 % amaranth has the strongest influence on the change in the height “h” of the biscuits. In the control sample, the thermal losses are significantly different from other samples. All other characteristics are close to the beginning of the coordinate system, which is why they are equally affected by changes in the content of amaranth in butter biscuits. The thermal inertia of the additive used affects the heat losses, therefore they have the highest levels in the control sample.

**Figure 8.** Principal component analysis of butter biscuits with amaranth

As can be seen from previous analyzes, the vector of selected traits can be reduced to 2 principal components because they describe 98 % of the variance in the data. A regression model of the type $A = f(\text{PC}_1, \text{PC}_2)$ was created, which describes the relationship between the calculated two main components and the amount of amaranth (A) in the butter biscuits. The evaluation results of this model are presented in Table 11. After removing the non-informative coefficients, a coefficient of determination $R^2 = 0.72$ was obtained. According to Fisher's criterion, $F \gg F_{\text{cr}}$, as well as according to Student's criterion, for all coefficients of the model, $t \gg t_{\text{cr}}$. Comparing p-value and the level of significance, $p \ll \alpha$. The standard error value is low (3.77). According to this analysis, the obtained model is adequate and describes with sufficient accuracy the experimental data. The red color means that the values are informative, according to the Statistica 12 software reference.

Table 11. Regression results

$R^2=0.72$ $F(3, 496)=422.51$ $p<0.00$ Standard Error of estimate: 3.77 $F_{cr}(3, 496)=2.62$ $t_{cr}(496)=1.65$						
N=500	b*	Standard error of b*	b	Standard Error of b	t(496)	p-value
-	-	-	8.42	0.26	32.74	0.00
Intercept	-	-	8.42	0.26	32.74	0.00
PC ₁	-1.03	0.03	-26.37	0.88	-29.87	0.00
PC ₂	-0.16	0.03	-9.72	1.85	-5.24	0.00
PC ₁ ²	0.31	0.04	20.81	2.57	8.10	0.00

The values are significantly different at $p<0.05$

The resulting model has the form, presented in equation 25:

$$A=f(PC_1, PC_2) \quad A = 8.42 - 26.37 \times PC_1 - 9.72 \times PC_2 + 20.81 \times PC_1^2 \quad (25)$$

Figure 9 shows the results of residuals analysis. With respect to the straight line, a normal distribution is observed in the normal probability graph of the residuals. The distribution of the residuals shows that they are located close to the normal distribution. From the analysis of the residues, it can be considered that the prerequisites of the regression analysis are fulfilled.

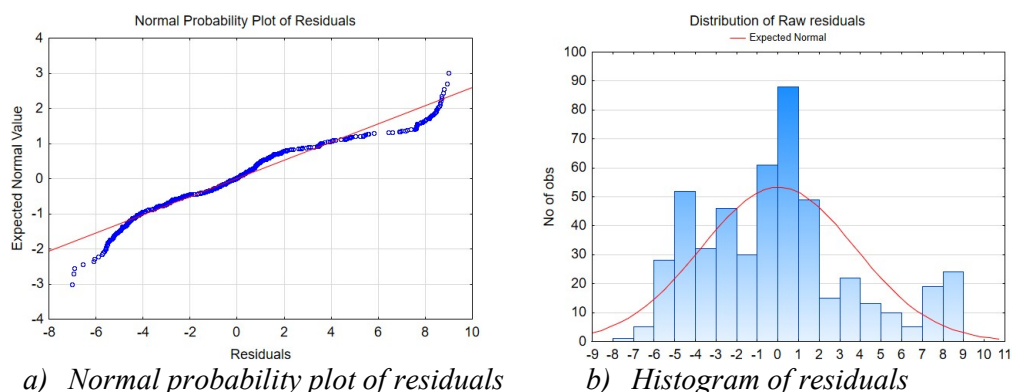


Figure 9. Residual analysis

Figure 10 shows the obtained model in general. The appropriate percentage of amaranth in butter biscuits is also applied. The above model of the type $A = f(PC_1, PC_2)$ was used. Applying an algorithm for linear programming, an appropriate amount of $A=12.87\%$ was determined. This value is found in the positive levels of PC_1 and the negative levels of PC_2 . It follows that the data for the first main component have a significant influence on the determination of the permissible amount of amaranth in butter biscuits.

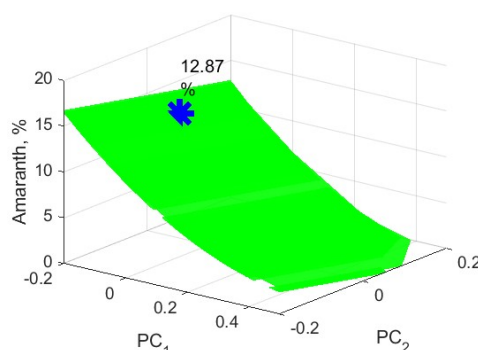


Figure 10. Determining the appropriate amount of amaranth in butter biscuits on the model $A=f(PC_1, PC_2)$

DISCUSSION

The results obtained in the present work complement those of the available literature. The established permissible level of amaranth in butter biscuits of 12.87 % is in the lower levels of the range 10 - 40 %. For the studied butter biscuits, the results are close to those set by Raihan *et al.* [8], who recommend putting 10 % amaranth flour in biscuits. The butter biscuits analyzed in this work may contain amaranth, which is in the range of 10 - 20 % reported by Saeid *et al.* [12]. Thus, the results obtained here complement and refine those reported in the available literature, introducing new data on the influence of amaranth on the physico-chemical, color, spectral and organoleptic characteristics of butter biscuits.

Compared to the ordinary sweet biscuits presented by Chauhan *et al.* [7], which may contain up to 60 % amaranth flour, the butter biscuits presented in the present work deteriorate at additive levels above 15 %. Thermal losses in butter biscuits are lower (up to 12 %) compared to ordinary sweet biscuits (up to 17 %). The spread factor for amaranth butter biscuits is up to 9 %, while for sweet biscuits it is lower (up to 7 %). These differences are due to the specific effect of the butter provided by the recipe on the rheological properties of the dough and its behavior during the formation of butter biscuits. The addition of amaranth flour leads to significant changes in the color characteristics of both butter and plain biscuits. Similar results for sweet biscuits have been reported by Sindhuja *et al.* [2]. The authors recommend 25 % addition of amaranth flour in ordinary biscuits. An expansion factor of up to 7 % has been reported, while in the present work, butter biscuits have higher values of this ratio (up to 9 %). In sweet biscuits, the increase in the amount of amaranth leads to a decrease in the coefficient of expansion, while in butter, on the contrary, it increases due to the influence of the greater amount of fat in the composition of the dough.

The analysis of the principal components used in the present work complements the results of Yadav *et al.* [14], in addition to representing the relationship between the amount of additive in biscuits and changes in their characteristics, in the present work the principal components were used to create a regression model applied in determining the appropriate amount of amaranth additive in butter biscuits. This complements the results of Zbikowska *et al.* [16]. In the present work, a linear programming algorithm is applied to the data of the regression model, which determines the appropriate amount of

amaranth additive in butter biscuits. Also, studies related to express automated biscuit analysis is needed as noted in [27] and [28].

CONCLUSION

The present paper presents the results of the impact assessment and the determination of the appropriate amount of amaranth in butter biscuits.

As a result of the analysis of the influence of the amount of amaranth on the main characteristics of butter biscuits, the appropriate amount of raw material in this product was determined. It was found that the addition of 12.87 % raw material of amaranth flour improves the physico-chemical and organoleptic characteristics of butter biscuits. Increasing the addition of amaranth leads to an increase in the size of the biscuits and the coefficient of spreading, respectively. On the other hand, the amount of raw material has a significant impact on the change in temperature losses. Also, higher levels of added amaranth lead to a reduction in the moisture content of biscuits.

An analysis of a total of 32 features describing the change in the physicochemical, geometric, organoleptic and optical properties of butter biscuits with the addition of amaranth was made. It was found that only 11 of them are informative. It has been proven that the geometric characteristics, moisture content, active acidity, electrical conductivity, consistency, taste, two color and one spectral index sufficiently reflect the changes in butter biscuits, depending on the amount of added amaranth.

The specific interrelation between the reduced data to two principal components of the created vector of 11 features has been studied. It has been found that this relationship can be described with an accuracy of up to 72 %.

Amaranth flour, due to its specific chemical composition and significant content of dietary fiber, can be used to obtain buttery biscuits with functional properties.

The results obtained improve and supplement those reported in the available literature. They can be used to improve the approaches and methods used so far to analyze butter biscuits with various herbal additives. The results can be used as preliminary baseline data for future evaluations and studies related to express automated biscuit analysis.

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