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COMPARATIVE ANALYSIS QUALITY OF INNOVATIVE PASTA FROM QUINOA

Krzysztof Gęsiński [1]*, Millena Ruszkowska[2]

[1] Bydgoszcz University of Science and Technology, 7 Prof. S. Kaliskiego St., 85-796 Bydgoszcz, Poland, Department of Biology and Plant Protection, gesinski@pbs.edu.pl
[2] Gdynia Maritime University, 81-87 Morska St., 81-225 Gdynia, Poland, Department of Quality Management, ORCID 0000-0002-4488-1087

* Correspondence author

Abstract: The aim of this study was to evaluate the quality of innovative quinoa pasta by assessing its culinary qualities. The products were compared with traditional wheat pasta. Four innovative products containing *Chenopodium quinoa*, available on the Polish market, were selected for the study. The culinary properties were determined by evaluating the weight gain factor, loss of dry matter during cooking, and an organoleptic evaluation and colour of pasta before and after cooking. The study showed that the culinary quality of the innovative products varied and depended on the raw material composition. A correlation was found between pasta properties and the proportion of quinoa and wheat flour in the products and the nutrient content. Pasta with a higher proportion of quinoa was characterized by good cooking properties.

Keywords: pasta, *Chenopodium quinoa*, culinary evaluation, sensory quality, instrumental colour assessment.

1. INTRODUCTION

In recent years, rural areas have undergone significant changes. Today, agriculture is no longer just a production activity, but an area of integration of many services, from food production to consumption, as well as food processing and ecosystem services [Parente et al. 2018]. An important aspect within the framework of sustainable rural development, is the possibility of implementing into agricultural production of new raw materials that can be used by the food industry for food production. Especially in an era of concern for food quality and safety, when combining environmental, social and economic objectives [Szczepanek, Prus and Knapowski 2018; Raquel, Dias and Costa 2021]. This fits into the pillars of sustainable agriculture and creates the need to cultivate alternative plant raw materials that can provide a new source of protein. In particular, the search for plant raw materials providing protein that will not be a source of food allergens like soy or a source of gluten like wheat and at the same time can be used for food production. Thus, it becomes important to implement new raw materials, both from the point of view of the agricultural production possibilities and the needs of the food industry, as it thus gives a guarantee of maintaining the financial stability of small individual farms, of which there are more in Poland compared to Western Europe [Parzonka and Hornowski 2017]. An example of a raw material that can be cultivated on small-scale individual farms is quinoa. In the case of quinoa, it is important to adapt the technology that enables its use as a main ingredient in a food product. An example is the production of innovative pasta products containing quinoa in their formulations.

Lifestyle changes, together with the increased availability of raw materials and the development of production technology, have led to a demand for new, innovative products. These include pasta products produced from traditional cereals as well as increasingly popular and widely available gluten-free and non-wheat pasta [Inglett et al. 2005; Menegassi and Leonel 2005; Fiorda et al. 2013]. Pasta is eaten all over the world, not only because of its nutritional value but for its sensory qualities as well [Chillo et al. 2008; Rodríguez et al. 2014].

Besides wheat flour and wheat bran, other ingredients can be added to pasta, such as buckwheat flour, flaxseed and protein concentrates as well as isolates from legumes such as soybean or amaranth. These may improve the nutritional value of pasta products particularly, such as the protein and fibre content.

Examples of innovative products include pasta containing quinoa, having a wide variety of shapes, sizes, raw material composition, additional ingredients, and quality characteristics.

Quinoa, which is considered a pseudo-cereal, is mainly grown for its seeds, which due to their chemical composition are used in numerous branches of the food industry. Quinoa is a good source of protein. According to Dębski and Gralak [2001], its content in quinoa seeds ranges from 12.1 to 15.4%, depending on varietal characteristics, climate, soil conditions and mineral fertilizers. Quinoa has a high content of essential amino acids, primarily lysine; the seeds of *Chenopodium quinoa* contain three times more lysine than wheat kernels and twice as much as rice. An important characteristic of quinoa seeds is that they contain no gluten proteins. Quinoa has a high content of saccharides, with starch accounting for the largest proportion (55–65%). The content of mono- and disaccharides is low, at 2–3%, and that of pentosans is 2–4%. The starch grain has an oval shape, and individual grains are composed of several hundred smaller grains ranging in size from 1 to 3 μm. A study by Inouchi, Glover and Fuwa [1987] showed that quinoa starch consists mainly of various types of amylopectins, with amylose accounting for 25–27%. Similar proportions of amylose and amylopectin are found in wheat and maize starch. However, the amylopectins in quinoa starch contain more long-chain fatty acids and fewer short-chain acids than the amylopectins in maize starch [Cacak-Pietrzak and Szybilska 2011; Gęsiński 2012].

The aim of this study was to evaluate the quality of innovative pasta based on culinary value, sensory quality, and instrumental colour assessment.

2. MATERIALS AND METHODS

The study was conducted on four pasta products obtained from innovative raw materials, containing flour from *Chenopodium quinoa*, *Triticum durum*, rice, and millet, with the addition of tomatoes, aubergine, spinach, beetroot, and organic herbs and spices (pastas I–IV), as well as a traditional wheat pasta designated in the study as sample 0. Five samples (from different production lots) of each of these pastas were tested.

The pastas varied in terms of shape, ingredients (Tab. 1), and chemical composition (Tab. 2), as reported by the product manufacturers. The products were stored in their packaging and the packages were opened immediately before testing. The pasta was left intact for the evaluation of the culinary properties.

Table 1. Raw material composition of the products used in the study

Pasta	Composition	
0	Wheat pasta	Semolina Triticum durum (100%)
I	Multigrain penne pasta with quinoa	Rice (85%), Chenopodium quinoa royal (10%), millet
II	Pasta Castagno BIO – Organic quinoa tube pasta with herbs	**Chenopodium quinoa whole grain flour (100%), mixed herbs, spinach**
III	Pasta Castagno BIO	Triticum durum flour (90%), Chenopodium quinoa 10%, eggplant, pepper, tomatoes, beet, oregano
IV	Organic Rice Quinoa Fusilli	Rice flour (75%), organic Chenopodium quinoa flour (25%)

Source: own study.

Table 2. Chemical composition of the tested pasta

Parameter	Value per 100 g of prepared product				
	0	I	II	III	IV
Energy value [kcal]	350	334	363	348	369
Protein [g]	12	9.0	11.3	10.9	10.7
Carbohydrates [g]	72	70.9	62.5	72.1	75.0
Fat [g]	1.5	1.6	6.0	1.8	0.7

Source: based on data declared by manufacturers on the unit packaging.

3. COOKING PROPERTIES

The cooking properties were characterized according to the method given by Obuchowski [1997]. The culinary value of pasta is defined by two indicators of the product's behaviour during culinary preparation, determined mainly by the quality of the raw material and the production technology. The first indicator is the increase in weight, i.e. the ratio of the weight of the cooked product to the weight of the uncooked product. The value of the weight increase characterizes the water-binding capacity of the product, and thus constitutes an economic parameter of its utility, defining the weight of the finished product obtained from a given weight of raw (uncooked) product. The second indicator used in the culinary evaluation of pasta products is dry matter loss, defining how much of the product is lost during hydrothermal treatment, and thereby determining the nutritional value of the product.

The methodology included an evaluation of the weight gain factor and dry matter loss of pasta, photographs were taken of the products before and after cooking and an organoleptic evaluation was carried out by a trained team of five people using a method based on the evaluation of five quality attributes, on a scale of 1 to 5. For the organoleptic evaluation of pasta quality, a scoring method was used, according to PN-A-74131:1999, based on which each quality characteristic was assigned a specific number of points on the following scale: 5 points – very good quality, 4 points – good quality, 3 points – satisfactory quality, 2 points – insufficient quality, and 1 point – unacceptable for the consumer.

The study also included an instrumental colour evaluation of the uncooked and boiled products according to the international CIE system, performed using a Konica-Minolta CR 400 colorimeter for the 2º standard observer and illuminant D65. The colour was measured in an optical glass measuring dish with a diameter of 34 mm. The CIE system allows definition of the characteristics related to both brightness and colour of the tested samples thanks to three variables: L* – brightness of the sample, expressed as a percentage from 0% (black) to 100% (white), a* – colour saturation: from green ("-a") to red ("+a"), and b* – colour saturation parameter: from blue ("-b") to yellow ("+b").

The colour saturation was calculated from formula (1):

$$C = \sqrt{\left(a^*\right)^2 + \left(b^*\right)^2} \tag{1}$$

3.1. Statistical analysis

The results of the measurements were statistically analysed using Statistica 13.3. The verification of the hypotheses on the variation of the mean level of the parameters of colour, weight gain factor, and sensory evaluation results was performed using one-way analysis of variance (Fisher-Snedecor F-test), supplemented with the NIR test, at an $\alpha = 0.05$ significance level. The null hypothesis was rejected if the test probability value "p" was less or equal to 0.05.

Principal component analysis (PCA) was also performed in order to visualize differences and similarities between the pastas (pastas 0, I, II, III and IV). In addition, a more detailed statistical evaluation of the properties of the pastas was performed by multivariate profile analysis [Brzeziński 2002; Jendrzejczak and Nowaczyk 2006]. The analysis of the cooked pasta took into account dry matter loss, weight increase, optimum cooking time, organoleptic evaluation, and colour saturation. Prior to the analysis, the data for all characteristics were converted to a 9-point scale. This scale was used to create models (profiles) describing the properties of the pastas. The dry and cooked products were compared separately.

Profiles were compared using Cohen's profile similarity coefficient, rc, calculated from (2) [Jendrzejczak and Nowaczyk 2006].

$$r_C = \frac{\sum_{i=1}^{n} A_i B_i + nm^2 - m\left(\sum_{i=1}^{n} A_i + \sum_{i=1}^{n} B_1\right)}{\sqrt{\left(\sum_{i=1}^{n} A_i^2 + nm^2 - 2m\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} B_i^2 + nm^2 - 2m\sum_{i=1}^{n} B_i\right)}} \tag{2}$$

where:

Ai, Bi – unitized values of features included in the compared profiles A and B,
n – number of features in the profile,
m – mid-point of the ranking scale.

The value for the coefficient was measured in the range (0 ±1). The profile similarity was negative if $rc < 0$ and positive if $rc > 0$. If rc was 0 or near 0, it was concluded that there was no similarity between the profiles. The closer the rc values were to (-1) or (+1), the stronger the similarity.

4. RESULTS

The study analysed four pasta products obtained from unconventional, innovative raw materials, as well as a traditional wheat pasta. Before performing the tests, we compared the ingredients given by the manufacturer on the packages (Tab. 1). The innovative pasta products were found to contain varying proportions of rice, wheat and quinoa flour. Pasta II had the largest share of quinoa flour – 100% flour from Chenopodium quinoa, followed by pasta IV, i.e. Organic Rice Quinoa Fusilli (25% quinoa flour). Pastas I and III contained 10% quinoa flour. Pastas I and IV additionally contained rice flour (Tab. 1).

Comparison of the chemical composition of the pasta products revealed that pasta IV had the highest calorific value of all the innovative pastas, with a high carbohydrate content and low fat content (0.7 g per 100 g of product) (Tab. 2). The highest protein content was noted for the wheat product – pasta 0, and among the innovative products, pasta II (11.3 g per 100 g of product), which also had the highest proportion of fat (6.0 g per 100 g of product) (Tab. 2).

4.1. Cooking properties

A significant characteristic of pasta is its capacity to ‘grow’, defined by the value of the weight increase, i.e. the factor by which the weight of the pasta increases after hydrothermal treatment. This is determined by the quantity and quality of protein, cooking time, and parameters of the production process. The analysis of variance showed that in the group of evaluated innovative products, the highest value of the weight gain factor was characteristic for pasta III (Tab. 3). A slightly lower value of the coefficient of weight increase was characterized by pasta II, which, despite a higher protein content (Tab. 3), was also characterized by a higher content of the hydrophobic component – fat, unable to bind and holding water during hydrothermal treatment (boiling). The value of the weight gain factor increases for wheat pasta 0 was the same as for innovative pastas II and III. Pasta I was characterized by the lowest coefficient. Referring to the research conducted by Sobota and Skwira [2009], the obtained value of the weight gain factor increases for pasta 0 was within the range of the weight of traditional wheat pasta obtained by the above-mentioned authors (2.14 to 4.14). On the basis of the studies, it was found that the weight gain of pasta during the cooking process correlated with the protein content. The highest weight gain factor was found in pasta 0, followed by pasta II, III and IV while the lowest weight gain occurred in pasta I, which had the least protein in the product composition. Therefore, Sobota and Skwira [2009] emphasize that the coefficient value is also strongly influenced by the form and shape of the pasta.

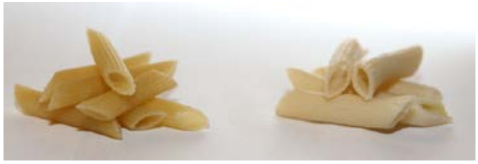
Table 3. Characteristics of the quality determinants of the tested pasta

Feature	Pasta	Mean	Standard deviation	Minimum value	Maximum value	p
Weight gain factor	0	2.25 c	0.02	2.23	2.27	0.000
	I	1.72 a	0.02	1.69	1.75	
	II	2.12 bc	0.03	2.08	2.16	
	III	2.23 c	0.05	2.18	2.30	
	IV	2.04 b	0.13	1.92	2.22	
Dry matter loss	0	9.8 a	0.01	9.8	9.8	0.000
	I	12.7 b	0.01	12.7	12.7	
	II	12.6 b	0,01	12.6	12.7	
	III	9.4 a	0.02	9.4	9.5	
	IV	13.3 c	0.01	13.3	13.3	

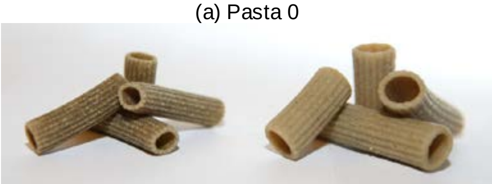
Source: own study.

Figure 1, a-e, show the products before and after cooking. Pasta III (Fig. 1d) maintained the best shape, characterizing the capacity to increase the weight of the pasta and confirming the values obtained for the weight increase. This was followed by pastas II (Fig. 1c) and IV (Fig. 1e), while pasta I (Fig. 1b) had the least favourable appearance and at the same time the smallest weight increase.

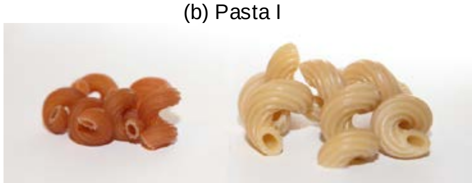
(a) Pasta 0



(b) Pasta I



(c) Pasta II



(d) Pasta III

(e) Pasta IV

Fig. 3. Tested pasta before and after cooking treatment, (a) – pasta 0, (b) – pasta I, (c) – pasta II, (d) - pasta III, (e) – pasta IV

Another significant factor determining the culinary characteristics of pasta is the dry matter loss during boiling. The level of dry matter loss is determined by the interaction of the protein matrix with starch granules. A large amount of protein ensures better starch binding and thus reduces dry matter loss, while the durability of the product is also influenced by the content of fat functioning as a binder [Cubadda et al. 2007]. According to Zawadzki [2005], the level of dry matter loss depends on the quantity and quality of gluten present in the pasta flour and on the degree of damage to the starch grains. Dry matter losses during boiling of high-quality pasta should not exceed 10% [Fardet et al. 1999]. In the present study, the amount of dry matter transferred to the water during cooking varied. The amount of dry matter that passed into the water during the boiling varied, as evidenced by the value of $p < 0.05$ (Tab. 3).

Pasta III and the wheat pasta (0) lost the least dry matter and thus were of better quality; the less dry matter that is transferred from the pasta to the water, the better the quality of the pasta. Thus those pastas with a higher content of wheat flour, and thus gluten, were characterized by lower dry matter losses during cooking. The greatest dry matter loss was noted for pasta IV. It is likely that the 75% share of rice flour and 25% share of quinoa, and thus the lack of gluten, had a detrimental effect on the quality of the pasta. Studies by Sobota and Dobosz [2010] and Marti et al. [2013] suggest that in the case of the innovative pastas, the lack of a gluten network may prevent the formation of a protein matrix strong enough to bind the starch granules. This probably led to the low quality of innovative pastas I, II and IV, characterized by substantial losses of dry matter.

The analysis of variance showed that each pasta studied had different levels of organoleptic characteristics ($p < 0.05$). Pasta IV was characterized by significantly lower ratings for all traits (Tab. 4).

Table 4. Organoleptic of tested pasta

Feature	Pasta	Mean	Standard deviation	Minimum value	Maximum value	p
Smell	0	5.00 b	0.00	5.00	5.00	0.001
	I	5.00 b	0.00	5.00	5.00	
	II	5.00 b	0.00	5.00	5.00	
	III	4.80 b	0.45	4.00	5.00	
	IV	4.20 a	0.45	4.00	5.00	
Taste	0	5.00 b	0.00	5.00	5.00	0.000
	I	5.00 b	0.00	5.00	5.00	
	II	5.00 b	0.00	5.00	5.00	
	III	5.00 b	0.00	5.00	5.00	
	IV	4.20 a	0.45	4.00	5.00	
Colour	0	5.00 b	0.00	5.00	5.00	0.042
	I	5.00 b	0.00	5.00	5.00	
	II	5.00 b	0.00	5.00	5.00	
	III	5.00 b	0.00	5.00	5.00	
	IV	4.60 a	0.55	4.00	5.00	
Shape	0	5.00 c	0.00	5.00	5.00	0.000
	I	4.00 b	0.00	4.00	4.00	
	II	5.00 c	0.00	5.00	5.00	
	III	5.00 c	0.00	5.00	5.00	
	IV	3.20 a	0.45	3.00	4.00	
Consistency	0	4.00 b	0.00	4.00	4.00	0.000
	I	4.00 b	0.00	4.00	4.00	
	II	5.00 c	0.00	5.00	5.00	
	III	5.00 c	0.00	5.00	5.00	
	IV	3.20 a	0.45	3.00	4.00	

Equal letter symbols next to the mean values indicate no significant difference between the means in the NIR test.

It is likely that the lower evaluation of pasta IV was influenced by the raw material composition, determining the shape of the pasta after cooking and its taste and consistency after the cooking process. The highest evaluations were recorded for pastas II and III. Seol and Sim [2017] noted the quality characteristics of noodles containing different amounts of germinated black quinoa. The powder of black quinoa with the highest antioxidative activation was selected and composite flour was prepared with 0, 5, 10, 15, and 20% of germinated black quinoa powder to produce the noodles. Consumer testing results indicated that the noodles with 15% of added germinated black quinoa showed the best results. Collectively, the evaluation of the quality characteristics and consumer acceptability indicated that adding 15% of germinated black quinoa to produce noodles is optimal.

Based on the colorimetric evaluation of the pasta colour and the results of the analysis of variance, a change in colour (brightening of the pasta, b*) was found after the hydrothermal treatment process. According to Lamberts et al. [2006], the initial colour of pasta was mainly affected by the drying process and its parameters used during the production process. After cooking, all the innovative macrons, including the control sample of wheat pasta 0, had a higher value of the L parameter (Tab. 5).

Table 5. Colour parameters of the pasta

Parameter	Pasta	Raw pasta	Boiled pasta	p
		Average value		
L*	0	35.0	45.2	0.000
	I	44.5	67.4	0.000
	II	38.2	51.9	0.000
	III	24.4	54.5	0.000
	IV	38.0	61.6	0.000
a*	0	-1.04	-0.30	0.000
	I	0.68	-0.88	0.000
	II	0.86	0.61	0.000
	III	7.23	1.80	0.000
	IV	-0.38	-1.25	0.000
b*	0	29.9	13.1	0.000
	I	18.4	19.5	0.425
	II	12.4	15.8	0.022
	III	8.9	14.4	0.000
	IV	17.8	11.4	0.009
C	0	29.9	13.2	0.000
	I	18.4	19.5	0.216
	II	12.4	15.8	0.033
	III	11.4	14.5	0.036
	IV	17.8	11.5	0.000

Source: own study.

The most noticeable colour change occurred in pastas II and III (Fig. 1b,d). The addition of herbs to these products contributed to the change in colour towards green (Tab. 5). The analysis of variance showed that only the values of parameters: b* and C of pasta I did not change after cooking ($p > 0.05$).

4.2. Comparison of the culinary properties of the pastas after boiling

Based on evaluation of the scree plot (Principal Component Analysis – PCA) and the eigenvalues of the components according to the Kaiser rule [Brzeziński 2002; Jendrzejczak and Nowaczyk 2006], two principal components were found to be significant (with values of 2.27 and 2.06). The first principal component was determined by the positive effect of the mean organoleptic score (Woo) and the colour saturation (C). The second was influenced by the negative effect of the weight gain factor (Wpw) and the positive effect of the dry matter loss (Ssm).

Figure 2 illustrates the graphic arrangements of these components. Negative correlations were found between the primary characteristics of dry matter loss and weight increase, between dry matter loss and mean organoleptic score, and between weight increase and colour saturation. These correlations show that as the weight increase becomes greater the colour saturation decreases, and a decrease in dry matter loss causes an increase in the organoleptic rating.

Figure 3 presents the distribution of the cooked pasta products based on the two principal components. It shows the greatest similarity between pastas III and 0.

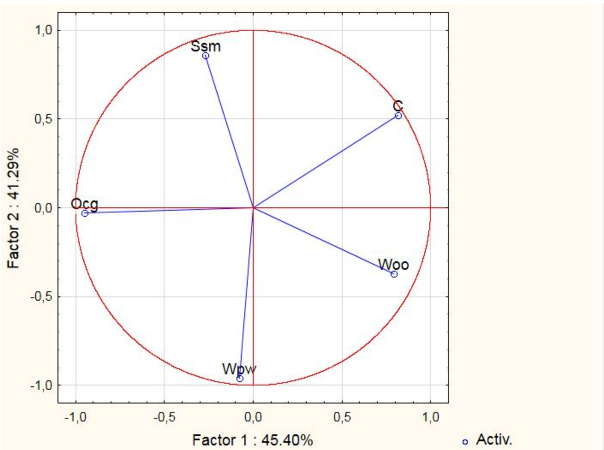


Fig. 2. Culinary properties of the tested cooked pasta according to the first two principal components (Ssm – dry matter loss, C – colour saturation, Woo – mean organoleptic score, Wpw – weight gain factor)

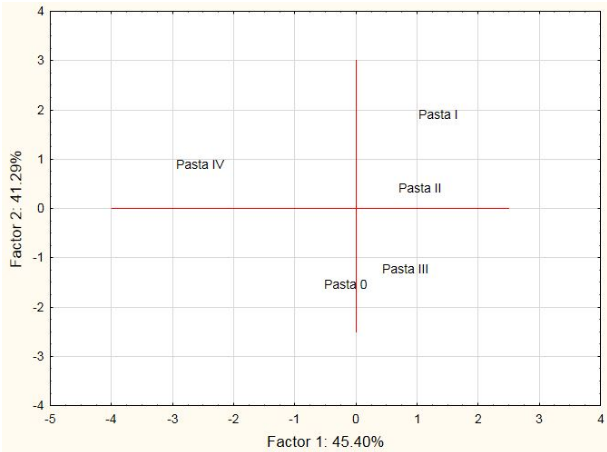


Fig. 3. Principal component analysis, distribution of the tested cooked pasta

Source: own study.

For a more precise evaluation of the culinary properties of the pasta, a profile analysis was performed. The models obtained are presented in Figure 4. Cohen's similarity coefficients, r_c, confirmed the highest similarity between pastas III and 0 ($r_c = 0.88$) (Tab. 6). This was linked to the composition of these products: wheat pasta 0 and pasta III with 90% wheat flour. Thus the culinary properties were a consequence of the large proportion of wheat in these two products. A negative similarity was noted between pastas III and IV and between pastas I and 0. Cohen's similarity coefficient, r_c, was negative: −0.60 and −0.58. The differences between these two pastas were also a result of their composition. Pastas I and IV contained over 75% rice flour, while III and 0 contained over 90% wheat flour, resulting in different culinary properties. The analysis also revealed fairly high similarity between pasta II (100% quinoa flour) and pastas I and III, which contained only 10% quinoa flour, with the rest consisting of wheat flour (III) or rice flour (I). This means that in terms of the culinary properties, the similarity of quinoa flour to wheat and rice flour is much greater than the similarity between wheat and rice flour. This confirms the substantial difference in the culinary properties of wheat flour and rice flour. These are determined by such factors as high dry matter losses and the low weight increases for rice flour (pastas I and IV) in contrast with wheat flour (pasta I), but also by the organoleptic evaluation. Pasta II, made from quinoa flour, had good culinary properties, which were reflected in its high organoleptic rating and high weight increase, despite the fairly large loss of dry matter.

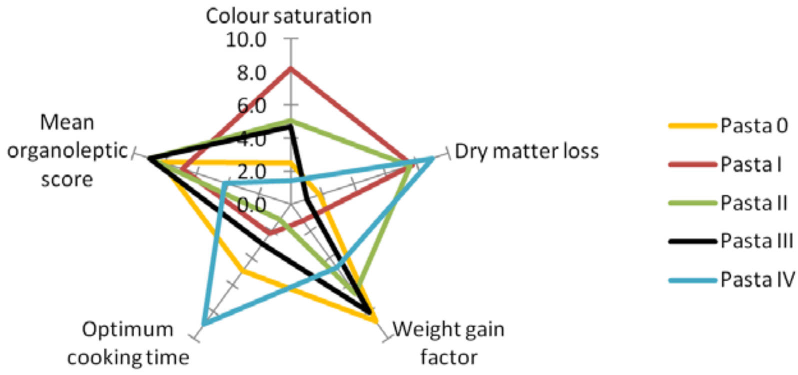


Fig. 4. Models of the culinary properties of the tested pasta after cooking

Source: own study.

Table 6. Characteristics of the quality determinants of the tested pasta

Pasta	II	III	IV	0
I	0.47	-0.22	-0.28	-0.58
II		0.44	-0.21	0.27
III			-0.60	0.88
IV				-0.17

Source: own study.

5. CONCLUSIONS

On the basis of the comparative assessment of selected determinants of the culinary value of the pasta studied, it was found that innovative pasta III – castagno bio, obtained from durum wheat and 10% quinoa flour, and innovative pasta II with 100% *chenopodium quinoa* content, as well as the evaluated traditional wheat pasta, were characterized by more favourable parameters from the point of view of quality.

The results suggest that the culinary qualities, particularly the increase in weight, of the innovative pastas were largely influenced by their protein content. The smallest increase in weight and relatively large dry matter loss were noted in the case of the innovative pasta which had the lowest protein content of all the evaluated products.

Thus the evaluation of the culinary properties led to the conclusion that the quality characteristics of the pasta were largely dependent on the raw material composition, as well as on the quality of the ingredients (including the content of basic nutrients) and the technological process used by the manufacturers of each product. The high proportion of quinoa (10 and 100%) in pasta gives it good cooking properties, similar to wheat pasta.

The results obtained in this study confirmed the possibility of using quinoa as a raw material for the production of pasta for the needs of the food industry.

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