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# INNOVATIVE PASTA FORMULATION BASED ON BARLEY/OAT FLOUR FORTIFIED WITH SEA BUCKTHORN POWDER

**Christine DRAGOMIR[1], Sylvestre DOSSA[1], Isidora RADULOV[2], Ersilia ALEXA[1], Mariana-Atena POIANA[1], Diana-Nicoleta RABA[3], Corina Dana MISCA[1], Ileana COCAN[1], Monica NEGREA[1], Gabriel SUSTER[3], Carmen Daniela PETCU[4]**

[1]University of Life Sciences "King Mihai I" from Timisoara, Faculty of Food Engineering, Calea Aradului 119, Timisoara 300645, Romania
[2]University of Life Sciences "King Mihai I" from Timisoara, Faculty of Agriculture, Calea Aradului 119, Timisoara 300645, Romania
[3]University of Life Sciences "King Mihai I" from Timisoara, Faculty of Management and Rural Turism, Calea Aradului 119, Timisoara 300645, Romania
[4]University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Veterinary Medicine, 105 Splaiul Independenţei, District 5, 050097, Bucharest, Romania

Corresponding author email: dianaraba@usvt.ro

***Abstract***

*This study aimed to design innovative pasta formulations with improved functional properties starting from a basic matrix consisting of a mixture of barley and oat flour which was fortified by including sea buckthorn powder in the recipe. For this purpose, in the novel pasta formulations, the barley/oat flour was replaced with sea buckthorn powder in proportions of 5, 10, 15, 20, and 25% (w/w). After preparation, pasta formulations were assessed in respect of proximate composition, total phenolic content, total flavonoid content and antioxidant activity expressed by ferric reducing antioxidant power (FRAP) value and the inhibition percentage of 2,2-diphenyl-1-picrylhydrazyl (DPPH). The results showed that the content of analyzed bioactive compounds and antioxidant properties of innovative pasta formulations increased significantly ($p < 0.05$) by using the sea buckthorn powder in the recipe. The highest increase for all investigated parameters was recorded for pasta in which barley/oat flour was substituted with 25% of the sea buckthorn powder. The obtained results reveal the desirability of using sea buckthorn to develop novel pasta formulas with enhanced functionality.*

***Key words***: *antioxidant properties, barley/oat, flour sea buckthorn, proximate composition.*

## INTRODUCTION

Food industry manufacturers are increasingly encouraged to seek out non-conventional raw materials for improving the nutritional quality of certain foods, due to the huge and growing demand from public decision-makers, scientists and consumers for healthy foods with improved nutritional characteristics (Romano et al., 2021). Cereal-based products such as pasta are a staple food that make up a significant part of the daily diet of millions of people around the world, making them an ideal matrix for enrichment with functional ingredients (Patel et al., 2011; Vignola et al., 2018). Pasta is mostly prepared with wheat flour or refined flour, despite its high starch digestibility and gluten content. On top of this, it contains a low nutritional profile, notably a low quantity of minerals, vitamins and bioactive constituents. Because of this state of affairs, several researchers have been working on the partial or total substitution of wheat by other cereals, either for their nutritionally rich and bioactive sources or to reduce or prevent allergenicity and/or gluten intolerance (Kumari & Gupta, 2022; Valle et al., 2021; Romano et al., 2021; Nilusha et al., 2019).

Whole grains, including barley (*Hordeum vulgare* L.), are important crops for human consumption, animal feed and industrial applications. Barley is an excellent source of phytochemicals. As such, it can be an excellent ingredient in the production of functional foods, including pasta and bakery products. It is therefore readily available and relatively cheap (Verardo et al., 2011, Suriano et al., 2018, Marconi et al., 2000). Barley is considered to

have higher antioxidant activity than oats, wheat and rye. This high antioxidant activity of barley makes it a useful natural means of preventing the development and progression of diabetes and obesity (Zielinski & Kozlowska, 2000). The majority of free phenolic compounds present in barley are flavanols and tocopherols, while bound phenolic compounds are mainly phenolic acids (Holtekjølen et al., 2006). In a study carried out by Robles-Ramírez et al. in 2020 entitled Barley bread with improved sensory and antioxidant properties, barley flour had a higher fat, ash, protein and dietary fibre content than wheat flour. The dietary fiber and ash content of barley flour was around five times higher than that of wheat flour. Total phenolic compounds and antioxidant activity increased when wheat flour was replaced by barley flour in the bread formulation. The addition of barley flour to bread formulations, for example, is known to dilute gluten proteins and break its chains during mixing (Gill et al., 2002).
Oats (*Avena sativa* L.) are of whole-grain cereals that contain higher concentrations of certain nutrients and phytochemical compounds (Rasane et al., 2015). Welch reported in 2016 in his study entitled: Nutritional composition and nutritional quality of oats and comparisons with other cereals, that oats contain bioactive phytochemical compounds such as vitamins, and phenolic acids. It is known for its nutritional benefits due to its high composition not only of soluble fiber but also of essential amino acids and lipids, particularly unsaturated fatty acids. Oats are also rich in minerals, vitamins and avenathramide, an antioxidant found only in oats (Rousta et al., 2022; Sandhu et al., 2017; Youssef et al., 2016; Sangwan et al., 2014). Daily consumption of a 90 g/day portion of oats in the form of hot cereal, for example, provides 13-15% of dietary energy (Welch, 2016).
Sea buckthorn (*Hippophae rhamnoides* L.), native to the Caucasus region, Central Asia and Western Siberia, belongs to the *Elaeagnaceae* family. It is a thorny deciduous shrub and is considered to have high ecological and economic value (Sytařová et al., 2020; Zeb, 2004; Yang & Kallio, 2001). Sea buckthorn offers several beneficial effects as it contains several bioactive substances characterized by antioxidant effects (Dupakb et al., 2022). It is safe and can be used as a valuable source of important bioactive compounds to create new enriched bread products for patients with cardiovascular disorders (Serban et al., 2019). It is rich in a variety of bioactive constituents and nutrients. The most abundant compounds found in sea buckthorn are lipophilic antioxidants, carotenoids, hydrophilic compounds such as phenolic acids, flavonoids and ascorbic acid. It is also rich in proteins, lipids, carbohydrates and minerals (Jaśniewska & Diowksz, 2021; Ciesarová et al., 2020; Tkacz et al., 2019).
The present study aims to design innovative pasta formulations with improved functional properties from a base matrix consisting of a mixture of barley and oat flour, enriched by adding sea buckthorn powder to the recipe.

## MATERIALS AND METHODS

### Preparation of pasta based on Barley/oat fortified with sea buckthorn powder

#### *Preparation of composite flours*

Table 1. Recipes for production of pasta samples

| | Quantity [g] | | | | | |
|---|---|---|---|---|---|---|
| **Ingredient** | P0 | P1 | P2 | P3 | P4 | P5 |
| **Barley/oat Flour** | 100 | 95 | 90 | 85 | 80 | 75 |
| **Sea buckthorn powder** | - | 5 | 10 | 15 | 20 | 25 |
| **Salt** | 1 | 1 | 1 | 1 | 1 | 1 |
| **Eggs (pcs)** | 1 | 1 | 1 | 1 | 1 | 1 |

Barley and oat flours were purchased from Pronat Timisoara, Romania. Sea buckthorn was purchased from local producers in the western region of Romania. In order to avoid the degradation of bioactive compounds in the sea buckthorn fruits, they were conditioned by drying in a dehydrator (Froilabo AC60/France, 1000 W) for 16 hours at 60°C. Dried dehydrated sea buckthorn fruits were ground with a Grindomix GM 2000 laboratory mill (Retsch GmbH, Haan, Germany) until they were transformed into a fine powder passed through a 60-mesh sieve. This powder was used to obtain the pasta according to the recipes presented in Table 1.

Six (6) types of composite barley/oat flours with sea buckthorn were made to produce the following 6 types of pasta:

- P0 (Pasta with 100% Barley/oat flour);
- P1 (Pasta with 95% barley/oat flour and 5% sea buckthorn);
- P2 (Pasta with 90% barley/oat flour and 10% sea buckthorn);
- P3 (Pasta with 85% barley/oat flour and 15% sea buckthorn);
- P4 (Pasta with 80% barley/oat flour and 20% sea buckthorn) and
- P5 (Pasta with 75% barley/oat flour and 25% sea buckthorn).

For the preparation of pasta, the raw materials are mixed after being weighed. This process results in a homogeneous dough. The pasta is dried in an airy space. After drying, the product is packed in bags and labelled (Figure 1).

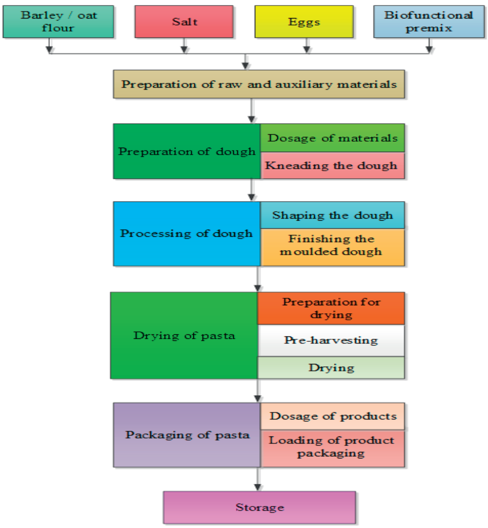


Figure 1. The technological scheme for obtaining pasta

**Proximate composition**

The proximate composition was determined in accordance with the following ISO Methods:

- Moisture (%) SR 91/2007 pct.10;
- Ash (%) SR ISO 2171/2010;
- Protein (%) SR EN ISO 8968-1:2014 ;
- Lipid (%) SR 91:2007 pct.14.4.

The carbohydrate content is obtained by subtracting 100 from the sum of the sample's protein, fat, moisture and ash contents.

The Energy value (Kcal/100 g) was determined according to the following equation:

Energy value (kcal/100 g) = (lipids x 9) + (carbohydrates x 4) + (proteins x 4)

**Phytochemical profile**

The total polyphenol content (TPC) was determined by the method of Folin-Ciocâlteu (Plustea et al., 2022) with some modifications. It is expressed in mg GAE/kg. Concerning the total flavonoid content (TFC) it is expressed in mg QUE/kg and was analysed according to the method described by (Plustea et al., 2022) with some modifications. The antioxidant activity is analysed by the FRAP method according to the method described by Cocan et al. (2022). It is expressed in µM $Fe^{2+}$/g.

All determinations were made in triplicate and the results are presented as mean values ± standard deviation (SD). Differences between means were analysed by a t-test (two samples assuming equal variances) using Microsoft Excell 365. Differences were considered significant when the p-values were less than 0.05.

## RESULTS AND DISCUSSIONS

The pasta obtained in this study is shown in Figure 2.


Figure 2. Pasta samples obtained

**Proximate composition**

The different types of pasta obtained were subjected to different analyses in order to establish the nutritional profile of each of them. The results of these analyses are presented in the following Table 2.

Table 2. Proximate composition of the pasta fortified with sea buckthorn

| Sample | Moisture (g/100 g) | Ash (g/100 g) | Protein (g/100 g) | Lipids (g/100 g) | NaCl (g/100 g) | Carbo-hydrates (g/100 g) | Sugar (g/100 g) | Energy value [kcal/100 g] |
|---|---|---|---|---|---|---|---|---|
| **P0** | 35.07 ± 1.14 | 1.28 ± 0.04 | 14.01 ± 0.46 | 5.16 ± 0.15 | 0.31 ± 0.01 | 44.17 | 0.14 ± 0.01 | 284.98 |
| **P1** | 41.14 ± 1.42 | 1.26 ± 0.04 | 13.56 ± 0.44 | 5.09 ± 0.15 | 0.31 ± 0.01 | 38.65 | 0.39 ± 0.01 | 259.83 |
| **P2** | 43.05 ± 1.48 | 1.24 ± 0.04 | 13.11 ± 0.42 | 5.02 ± 0.14 | 0.31 ± 0.01 | 37.28 | 0.63 ± 0.02 | 251.73 |
| **P3** | 44.96 ± 1.52 | 1.23 ± 0.03 | 12.65 ± 0.40 | 4.94 ± 0.13 | 0.30 ± 0.01 | 35.92 | 0.88 ± 0.02 | 243.63 |
| **P4** | 46.86 ± 1.59 | 1.21 ± 0.03 | 12.20 ± 0.37 | 4.87 ± 0.13 | 0.30 ± 0.01 | 34.55 | 1.13 ± 0.04 | 235.54 |
| **P5** | 48.77 ± 1.66 | 1.19 ± 0.03 | 11.75 ± 0.35 | 4.80 ± 0.12 | 0.30 ± 0.01 | 33.18 | 1.38 ± 0.04 | 227.44 |

Analysis of the results from this table shows that the moisture content changes with the addition of sea buckthorn powder to the pasta composition. From 41.14 g/100 g for the sample with 5% sea buckthorn powder, the moisture content rose to 48.77 g/100 g for the sample with 25% sea buckthorn. The Sea Buckthorn powder would therefore have a higher moisture content than the barley/oat mixture.

Our results also show that the amount of minerals in the pasta decreases as the amount of sea buckthorn increases. Mineral concentrations were respectively as follows: 1.28; 1.26; 1.24; 1.23; 1.21 and 1.19 g/100 g for P0, P1, P2, P3, P4 and P5. The barley/oat mixture is richer in minerals than sea buckthorn. This is justified by the fact that the ash content of barley and oats is higher than that of sea buckthorn. Sea buckthorn would therefore provide fewer minerals and proteins than the barley/oat mixture. Rivera-Dommarco's study of the 2001 Food Composition and Nutrition Table shows that the ash content of sea buckthorn berries is 0.3 g/100 g, while the mineral content of oats and barley is 2 g/100 g (Rousta et al., 2022) and 3.38 g/100 g (Zheng et al., 2022) respectively. The mineral content of each of our different samples is higher than that obtained for durum semolina dough (0.83 ± 0.009 g/100 g) by Hidalgo et al., 2020. This confirms that the different flours used for pasta formulation in our study are good sources of minerals.

As with the minerals, the increase in sea buckthorn content in the various samples is synonymous with an increase in protein content. From 14.01 g/100 g in the control sample, the protein concentration dropped to 13.56 g/100 g in the sample with 5% sea buckthorn. The sample with 25% sea buckthorn had 11.75 g/100 g protein. This suggests that sea buckthorn is responsible for the drop in protein levels in pasta. Sea buckthorn, therefore, has a lower protein content than barley and oats. Protein levels are respectively 0.6 to 2.5 g/100 g (Tan et al., 2018; Liang et al., 2011); 11.3 g/100 g (Aly et al., 2021) and 11.1 (Rousta et al., 2022) for sea buckthorn, barley and oats. Pasta obtained from durum wheat semolina was less rich in protein (between 11.3± 0.1 and 11.4 ± 0.05 g/100g) than our pasta (Hidalgo et al., 2020; Panghal et al., 2019).

The NaCl content of the compounds remained virtually unchanged from sample to sample. Lipid and carbohydrate content followed the same pattern as mineral and protein content. For each of these parameters, the higher the quantity of sea buckthorn, the lower they became. For lipids, we have respectively 5.16; 5.09; 5.02; 4.94; 4.87 and 4.80 g/100 g for P0, P1, P2, P3, P4 and P5. Carbohydrates fell from 44.17 g/100 g in the control sample to 33.18 g/100 g. Our samples have a higher lipid content than that obtained for durum wheat semolina dough by Hidalgo et al. in 2020, which was 1.69± 0.05 g/100 g. In our study, the addition of sea buckthorn would be responsible for the lower carbohydrate and lipid content of pasta. As far as lipids are concerned, they were 2.04 g/100 g (Zheng et al. 2022) and 7.7 g/100 g (Rousta et al., 2022) in barley and oats respectively, whereas sea buckthorn fruit had a lipid content of between 0.8 and 5.9 g/100 g (Tan et al., 2018; Liang et al., 2011). The same was true of carbohydrate content, which was lower in sea buckthorn (between 9.5 and 17.9 g/100 g) than in barley (69.3 g/100 g) and oats (55.7 and 59.9 g/100 g) (Aly et al., 2021; Tan et al., 2018; Sandhu et al., 2015; Liang et al., 2011).

Sugar levels in pasta increased by 1.24 g/ 100 g between the control sample (P0) and the sample containing the highest sea buckthorn content (P5). This could be explained by the high sugar content of sea buckthorn fruit. Sugar levels in sea buckthorn fruit ranged from 3.4 to 6.7 g/100 g in the studies by Tan et al. in 2018 and Liang et al. in 2011. According to our results, although sea buckthorn is a source of sugar, it reduces the energy intake in pasta. There was a significant decrease in energy intake from one sample to another when sea buckthorn was added. The control sample (P0) had a kcal intake of 284.98 per 100 g, compared with 227.44 kcal/100 g for the sample with 25% sea buckthorn.

**Total polyphenols content (TPC)**

Total polyphenol content was determined for each sample. The results are shown in the Figure 3.

The results show that the polyphenol content of the pasta obtained was in the range 701.26 and 2211.24 mg GAE/kg. Furthermore, as the amount of sea buckthorn in the pasta increased, the polyphenol content increased significantly.

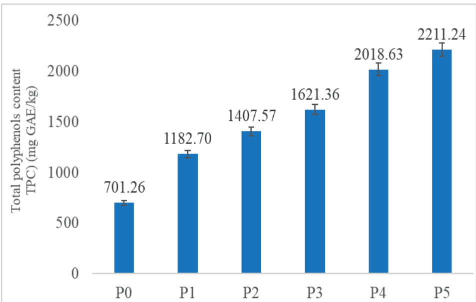


Figure 3. Total polyphenol content for the pasta samples supplemented with sea buckthorn

Between the sample with 5% (P1) sea buckthorn and that with 25% (P5), there was an increase in total polyphenol content of 1028.54 mg GAE/kg. Sea buckthorn is believed to be responsible for the increase in total polyphenol content of the pasta. In the work of Guo et al. on the comparative evaluation of phytochemical profiles, antioxidant and antiproliferative activities of sea buckthorn berries (*Hippophaë rhamnoides* L.), total polyphenol content ranged from 27.6 ± 1.9 to 38.7 ± 1.3 mg GAE/g. On the other hand, in the studies by Bei et al. the total polyphenol content was 0.44 ± 0.02 in oats, and 2.22 ± 0.192 in barley in the studies by Suriano et al. on the phenolic acid profile, nutritional and phytochemical compounds and antioxidant properties of coloured barley grown in southern Italy.

**Total flavonoids content (TFC)**

Once the total polyphenol content of the various samples had been determined, they were then tested for flavonoid content. The Figure 4 below shows the flavonoid content of the various pastes.

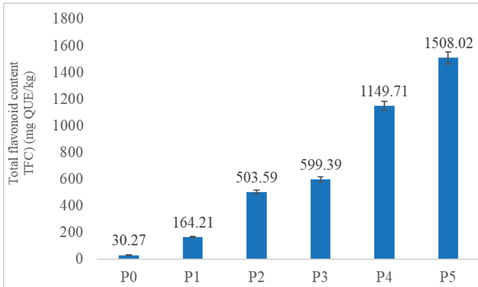


Figure 4. Total flavonoid content for pasta samples supplemented with sea buckthorn

Flavonoids are compounds of real importance to the human organism, reducing cholesterol and triglycerides in the blood. They are the main active substances in herbal medicines for the treatment of cardiovascular disease. Flavonoids have a significant purifying effect on blood tartar, old blood cells and waste products in the blood. They reduce capillary permeability, improve blood vessel flexibility, prevent and improve angina pectoris and cardiac function (Chen et al., 2023). In our study, the results show that from P0 to P5 there is a significant increase in flavonoid content. Thus, the increase in sea buckthorn powder in the recipe corresponds to the increase in flavonoid content. There were 30,266; 164,207; 503,593; 599,393; 1149,713 and 1508,020 mg QUE/kg for P0, P1, P2, P3, P4 and P5 respectively. The total flavonoid content (TFC) of oat cultivar flour varied significantly from 433 to 612 μg EC/g in the work of Sandhu et al. on Effect of heating on the physical, functional and antioxidant properties of oat cultivar flour (*Avena sativa* L.).

**Antioxidants activity (AA)**

As with total polyphenol content and flavonoid content, antioxidant activities increased proportionally with increasing sea buckthorn content (Figure 5).

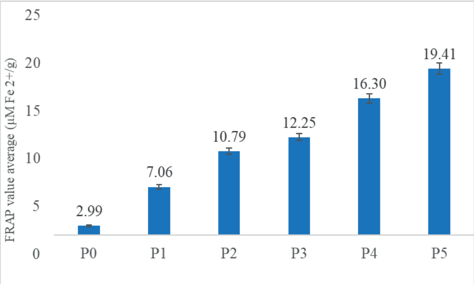


Figure 5. AA (FRAP) of the pasta samples supplemented with sea buckthorn

The antioxidant activity of the different pastes obtained was in the range of 2.988 and 19.411 µM Fe2+/g, i.e. an increase in antioxidant activity of 16 µM Fe2+/g. This increase would be due to the better antioxidant activity of sea buckthorn compared to the barley/oat mixture.

## CONCLUSIONS

The aim of this study is to meet current consumer dietary needs. The current trend is to formulate food products with a high nutritional and phytochemical profile, not forgetting the physical aspect. With this in mind, functional pastes based on barley and oats have been formulated and enriched at different substitution levels with sea buckthorn powder. The greatest increase in all the parameters studied was recorded for doughs in which barley/oat flour was replaced by 25% sea buckthorn powder. The results obtained show that it is desirable to use sea buckthorn to develop new pasta formulas with improved functionality.

At the end of this study, the phytochemical power of sea buckthorn was determined. It was also found that the mixture of barley and oats could undoubtedly form the basis for the production of food pastes to replace wheat.

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