applied sciences

MDPI

Article

Effects of *Allium ursinum* L. Leaves and Egg Amount on Quality Attributes, Polyphenol Content, and Antioxidant Capacity of Pasta

Cristina Adriana Rosan [1,†], Mariana Florica Bei [1], Alexandra Cristina Tocai (Moţoc) [2], Manuel Alexandru Gitea [3,†] and Simona Ioana Vicas [1,2,*]

1 Department of Food Engineering, Faculty of Environmental Protection, University of Oradea, 26 Gen. Magheru Street, 410048 Oradea, Romania; crosan@uoradea.ro (C.A.R.); mbei@uoradea.ro (M.F.B.)
2 Doctoral School of Biomedical Science, University of Oradea, 410087 Oradea, Romania; tocai.alexandra@gmail.com
3 Department of Agriculture, Faculty of Environmental Protection, University of Oradea, 26 Gen. Magheru Street, 410048 Oradea, Romania; mgitea@uoradea.ro
* Correspondence: svicas@uoradea.ro
† These authors contributed equally to this work.

Abstract: Pastas enriched with vegetables are premium nutritious products and their consumption can bring significant health benefits. Recent studies have reported a high content of bioavailable phytochemical compounds in *Allium ursinum* L.; as such, it can be used in the development of functional food products. This study involved the evaluation of 10 varieties of pasta. Five of these varieties were made from white flour and varying amounts of egg (Ctrl_1–Ctrl_5). The other five varieties (AU_1–AU_5) contained fresh shredded wild garlic leaves in equal proportions (20 g) in addition to the corresponding ingredients (white flour and egg). All pasta variants were investigated for their cooking properties and the presence of bioactive compounds and antioxidant capacity in the raw and cooked pasta. Sensory analysis was conducted on all types of cooked pasta, and results indicated that the pasta with the least quantity of eggs was the most favoured variant. Additionally, the pasta that was enhanced with wild garlic leaves received the highest rating for "overall quality". According to our results, the optimal cooking time (OCT) increased when the quantity of eggs was raised, but when wild garlic leaves were present, OCT decreased in comparison to the control samples. A significant decrease ($p < 0.05$) in the cooking parameters, swelling index, and water absorption was observed in both egg pasta (Ctrl) and egg pasta enriched with *A. ursinum* L. (AU). However, compared to the corresponding egg pasta, the presence of wild garlic in pasta generally produced higher values in SI and WA. Pastas enriched with wild garlic are rich in polyphenols (TPh), with a content ranging from 82.44 to 94.62 µg GAE/g dw, and also exhibit antioxidant properties. The amount of total polyphenol significantly decreases ($p < 0.05$) during cooking varies depending on the composition of the pasta. The pasta with the highest egg content (AU_5) had the lowest loss of polyphenols, equivalent to 55.35%. Our investigations indicate that producing pasta with eggs and fresh wild garlic leaves results in a valuable food product with a good sensory score, enriched in bioactive components, with essential nutrients that maintains cooking qualities.

Keywords: pasta; cooked quality; *A. ursinum* L.; wild garlic; antioxidant properties; phenolic compounds; sensory quality

Citation: Rosan, C.A.; Bei, M.F.; Tocai, A.C.; Gitea, M.A.; Vicas, S.I. Effects of *Allium ursinum* L. Leaves and Egg Amount on Quality Attributes, Polyphenol Content, and Antioxidant Capacity of Pasta. *Appl. Sci.* **2024**, *14*, 7517. https://doi.org/10.3390/app14177517

Academic Editors: Monica Gallo, Joanna Kapusta-Duch and Barbara Borczak

Received: 30 July 2024
Revised: 17 August 2024
Accepted: 23 August 2024
Published: 25 August 2024

1. Introduction

Pasta is regarded as an essential type of food for human nutrition [1] and is a traditional and popular dish in some cuisines around the world [2]. It is also an easily prepared and commercially accessible product [3]. Pasta is the second most popular food worldwide in terms of consumer preferences, right after bread [4]. The most recent report (2022) from the

International Pasta Organization (IPO) lists Italy, Tunisia, Venezuela, Greece, and Peru as the top five pasta-consuming nations across the globe [5].

Muresan et al. (2017) [6] define pasta as food products that are boiled, extruded, and dried, with water and wheat or wheat flour as their main ingredients. The most popular ingredient used in their production is durum semolina, valued for its high protein and high gluten content [7]. It determines both the quality of cooked pasta and its yellow colour, which in turn influences the consumers' choice.

In terms of their nutritional values, traditional pasta made exclusively from durum semolina contains 3.6% carbohydrates and fibre, 14.3% protein, 1.79% fats, and iron (1.29 mg/100 g) [8]. However, for financial reasons, pasta manufacturers in many countries use either common wheat flour, which is significantly less expensive than durum semolina, or a combination of common wheat flour and semolina [9]. Since pastas made from these blends is of lower quality than pasta made from durum wheat, adding egg (whole, yolk, pasteurized, frozen, or powdered) into their composition improves their cooking parameters, nutritional value, and colour [10]. Pasta dough that has more egg added to it will also have a more intense yellow tint because yolks contain carotenoid pigments. Technologically speaking, as the egg content increases, the elasticity of the dough decreases and the mixing time is shortened because the protein penetrates the matrix of the product [2].

Studies indicate that poor nutrition is thought to be the root cause of many health issues [11]. In this sense, many experts are researching the innovation of functional foods in an effort to find quick and workable ways to fortify food products with plant-based ingredients (leaves, fruits, cereals, grains, vegetables, tescocholine, seeds, and mushrooms). Adding these ingredients to products in different forms—such as powdered, pureed, shredded, or encapsulated—can enhance the quality of life for consumers.

Among food products, pasta has undergone extensive testing. Thus, the pasta composition included the following: sweet corn "milk" residue [12], kelp (*Artospira Phratensis*) [13], wild garlic (*Allium ursinum* L.) [2], artichoke (*Cynara scolymus* L.) [14], mango (*Mangifera indica* L.) seed powder [15], onion peel flour [16], spinach (*Spinacia oleracea* L.) and red cabbage (*Brassica oleracea* convar. *capitata* var. *capitata f. rubra*) [17], carrot puree, red beet, spinach and canned tomato puree [18], celery root powder (*Apium graveolens* L.) and sugar beet (*Beta vulgaris* L.) pulp [19], asparagus (*Asparagus officinalis* L.) flour [20], raspberries, blackcurrants, redcurrants, and blackberries [21].

Alium ursinum L. (AU), also known as wild garlic, ramson, or bear's garlic, is a perennial plant that is widely distributed throughout Europe. It belongs to the Amaryllidaceae family and is a member of the genus *Allium*. It grows best in shady, humid environments close to watercourses or deciduous forests [22–24].

Studies by Kovacevici et al. (2023) [25] revealed the presence of essential amino acids in wild garlic leaves, of which threonine, valine, methionine and leucine are predominant. Wild garlic is also a source of secondary metabolites, quercetin and kaempferol being the predominant flavonoids.

The plant is known for its rich content of sulphur compounds, alline, and methionine, due to which wild garlic exhibits antioxidant capacity [26–30], and cytotoxic on tumour cells [31]. Research published in the literature has shown how beneficial these substances are for treating a variety of ailments, strengthening the immune system, and preventing cardiovascular diseases [29]. *A. ursinum* L. is characterized by a strong garlic (*A. sativum*) flavour due to the presence in their composition of sulphur, odourless compounds such as cysteine-sulfoxides. When tissue is destroyed, these sulphur-based compounds undertake hydrolysis reactions that are catalysed by endogenous enzymes called lyases. This process produces a wide range of volatile compounds. Thiosulfinates, mainly allicin, are the primary product of the enzyme lyases present in wild garlic as the alline substrate [24]. Although these compounds have been shown to have a positive impact on health, their flavour may influence consumer acceptance.

To our knowledge there is only one study that has used wild garlic leaves in pasta [2], under three forms, including the encapsulated form, having as the encapsulation matrix maltodextrin, probably to mask the strong aroma of the wild garlic. But, maltodextrin is not the most suitable encapsulation material because it is less effective in masking the strong odour and taste compared with other encapsulating materials Another aspect which may be a limiting factor in the use of wild garlic leaves in pasta is given by the colour. Some consumers accept only the classic yellow colour for pasta, but others might associate the green colour of pasta with healthy natural ingredients.

Compared to other studies that have used only plants as a fortification of pasta, the novelty of this study is the inclusion in the composition of pasta at the same time both the egg, which brings a high nutritional value, and the leaves of wild garlic that comes with its contribution in bioactive compounds. In light of the previously mentioned ideas, we added fresh *A. ursinum* L. leaves to the pasta dough at a fixed quantity (20 g) and varied the amount of egg from 0–100 g for the study. We measured the impact of integrating the aforementioned components on the antioxidant potential, total polyphenol content of cooked and uncooked pasta, and looked at sensory attributes such as colour, texture, and cooked quality of enriched pasta.

2. Materials and Methods

2.1. The Process of Preparing the Leaves of A. ursinum L.

Fresh leaves were collected at the end of March 2024, on the day of pasta preparation, from a population of *A. ursinum* L. located in the Băile Felix Forest, Bihor County, Romania, located by plus code XPJ+37X Băile Felix and the following GPS coordinates: 46°59′06.9″ N 21°58′50.7″ E. The identification of *A. ursinum* L. plant was made at the Department of Pharmaceutical Botany at the University of Oradea, Faculty of Medicine and Pharmacy. A specimen of *A. ursinum* L. was kept in the Herbarium of the Faculty of Medicine and Pharmacy Oradea, Romania, registered in NYBG Steere Herbarium, under the code: UOP 05718.

In order to be incorporated into the pasta composition, the fresh leaves were subjected to preliminary processing steps (Figure 1). Thus, after harvesting, the leaves were immediately brought to the laboratory where they were washed, and placed in boiling water for 5 seconds in order to modify their texture. The opaque leaves were thoroughly drained, scored with a knife, and thus used for dough formation.

Figure 1. Preparation of fresh leaves of *A. ursinum* L.

2.2. Pasta Preparation

The pasta was made from white flour of common wheat (*Triticum aestivum* L.) type 000 and organic eggs of chicken (*Galus domestica*), size M, purchased from the local commercial network. Eggs were transported and stored in refrigerated (4 °C) conditions until processing (1 day).

Using the aforementioned protocol, five distinct pasta variations (Table 1) were made with fixed amounts of minced and scalded wild garlic leaves (20 g) and varied amounts of egg (0 g, 10 g, 20 g, 50 g, and 100 g). To highlight the part that wild garlic plays for the cooking qualities of pasta, five additional pasta variations were made without the addition of wild garlic and with the same different egg concentrations (Table 1). The dough obtained by the aforementioned processes was kneaded by hand for 10 min, left to rest, then it was shaped to 3 mm thickness and cut into 7 mm wide strips using a Grűnberg GR 155 type noodling machine. The pasta obtained were dried at a temperature of 30 °C in an oven (Nitech Pol Eko oven, model CLN 53, Wodzisław, Poland) to constant weight.

Table 1. Formulations of egg pasta enriched with wild garlic leaves.

Pasta Samples	Common Wheat Flour (g)	Egg (g)	*A. ursinum* L. Leaves (g)	Water (ml)	Salt (g)
AU_1	220	0	20	100	0.5
AU_2	220	10	20	90	0.5
AU_3	220	20	20	80	0.5
AU_4	220	50	20	50	0.5
AU_5	220	100	20	0	0.5
Ctrl_1	240	0	0	100	0.5
Ctrl_2	240	10	0	90	0.5
Ctrl_3	240	20	0	80	0.5
Ctrl_4	240	50	0	50	0.5
Ctrl_5	240	100	0	0	0.5

Ctrl_1, Ctrl_2, Ctrl_3, Ctrl_4, and Ctrl_5 represent the experimental variants of egg pasta containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg; AU_1, AU_2, AU_3, AU_4, and AU_5 represent the experimental variants of egg pasta containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg and a constant concentration of wild garlic (20 g).

All pasta variants obtained were tested for cooking quality parameters, total polyphenol content, and antioxidant capacity, with the experimental design being shown in Figure 2.

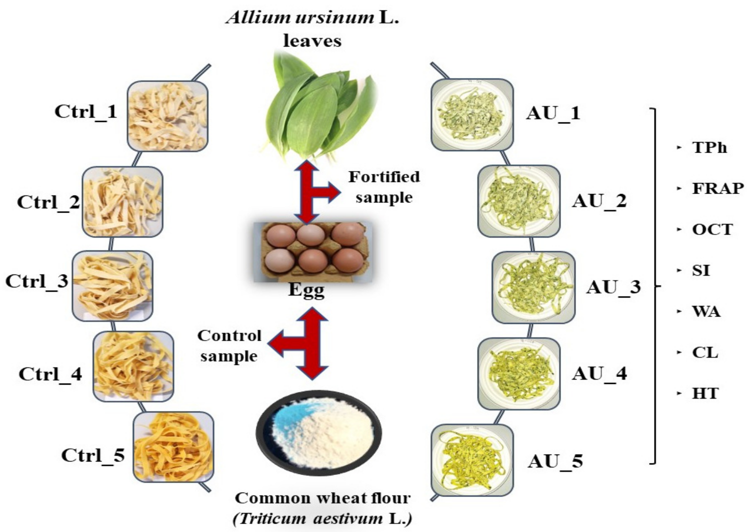


Figure 2. Experimental design. Ctrl_1, Ctrl_2, Ctrl_3, Ctrl_4, and Ctrl_5 represent the experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg; AU_1, AU_2, AU_3, AU_4, and AU_5 represent the experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg and a constant concentration of wild garlic leaves (20 g). TPh—Total polyphenols, FRAP—Ferric-Reducing Antioxidant Power, OCT—Optimal Cooking Time, CL—Cooking Loss, SI—Swelling Index, WA—Water Absorption, HT—Hydration.

2.3. Determination of Cooking Properties

Consumer acceptability of a pasta assortment is reflected by the indicators of cooking quality, appearance, and sensory properties of pasta [21].

Optimum cooking time (OCT): In 300 ml of boiling water, without salt added, 25 grams of pasta was immersed and cooked, determining at 30 seconds intervals the appearance of the starch core by pressing a piece of pasta between 2 glass slides. Pasta whose central starch core disappeared was considered to be optimally cooked [32].

Cooking loss (CL): Determined when boiling 10 grams of pasta at the optimal time in 100 mL of water without the addition of sodium chloride. After boiling, the pasta was drained, the resulting boiling water was brought to the initial volume (100 mL), homogenized, then a volume of 25 mL was measured and placed in an oven at 105 °C, where it was kept until the residue reaches constant weight. The cooking loss (CL) was calculated (Equation (1)) by the difference between the dry residue mass (DRM) and the initial dry dough mass (DDM) [33].

$$CL = \frac{DRM}{DDM} \times 100 \tag{1}$$

The swelling index (SI) was determined by cooking 10 g of pasta at OCT. The cooked pasta was drained for 1–2 min, weighed and dried for 4 h at 105 °C until it reached constant weight. The determination of the swelling index (SI) was calculated according to Equation (2) [34].

$$SI = \frac{v_0 - v_1}{v_1} \tag{2}$$

where v_0 = dry pasta weight and v_1 = cooked pasta weight

Water absorption (WA) represents the amount of water absorbed by the pasta during cooking at OCT and was calculated according to Equation (3) [32].

$$WA = \frac{m - m_0}{m_0} \times 100 \tag{3}$$

where m = the weight of cooked pasta and m_0 = the weight of raw pasta

The hydration test (HT) was determined by immersing 5 g of pasta in a beaker with 100 ml of water maintained at 25 °C. At different time intervals of 5, 10, 15, 30, 60, 90, and 180 minutes, the samples were drained for 1 minute, weighed, and the process was repeated for the next time interval. The results were calculated according to Equation (4) [32].

$$HT = \frac{v_1 - v_0}{v_0} \times 100 \tag{4}$$

where v_1 = the weight of the raw hydrated pasta and v_0 = the weight of the dry raw pasta

2.4. Extraction and Spectrophotometric Determination of Total Phenols from Raw and Cooked Pasta

Extraction of phenolic compounds. Using the procedure outlined by Jabrec et al. (2015) [35] the free fraction of phenolic compounds in pasta samples was determined. Briefly, 1 g of ground sample of uncooked and cooked pasta was moistened with 2.5 mL ethanol:water dilution in 4:1 (*v*/*v*) ratio, sonicated at 40 °C for 15 min (machine name), centrifuged for 10 min at 5000 rpm (NÜVE NF 200 BENCH TOP CENTRIFUGE, Ankara, Turkey) and the supernatant was used for the determination of total phenolic compounds and antioxidant capacity.

The total phenolic compounds content in the uncooked and cooked pasta was measured using the Folin–Ciocalteu method described by Singleton et al. (1999) [36], with minor modifications [37]. Briefly, 1.7 mL distilled water was mixed with 0.1 mL hydroalcoholic extract of pasta, 0.2 mL freshly prepared Folin–Ciocalteu reagent (1:10 dilution, *v*/*v*), and 1 mL Na_2CO_3 7.5% solution. The samples were then vortexed and incubated in the dark at room temperature for 2 h. The absorbance was read at 765 nm using a spectrophotometer (Shimatzu miniUV-Vis spectrophotometer, Kyoto, Japan) and the results were expressed as mg gallic acid equivalents (GAE)/g dry weight (dw).

2.5. Determination of Antioxidant Capacity

The antioxidant capacity of the pasta samples was determined by the Ferric Reducing Antioxidant Power (FRAP) method using the protocol described by Benzie and Strain, 1996 [38] with minor modifications [39]. This method is based on the antioxidant power of the samples, i.e., the ability of the pasta extract to reduce in acidic medium Fe^{3+} from the tripyridyltriazine Fe $(TPTZ)^{3+}$ complex to Fe^{2+} from the blue-coloured Fe $(TPTZ)^{2+}$ complex. FRAP reagent is prepared fresh by mixing 300 mM acetate buffer (pH 3.6) with 20 mM $FeCl_3$ and 10 mM TPTZ solution in the ratio 10:1:1 (*v*/*v*/*v*). The sample preparation consisted of mixing 0.1 mL of pasta sample extract with 0.5 mL of FRAP reagent and 2 mL of distilled water, followed by vortexing and incubation for 1 h in the dark at room temperature. The absorbance was measured at 595 nm using a spectrophotometer (Shimatzu miniUV-Vis spectrophotometer, Kyoto, Japan). The results were expressed as µmol TE (Trolox equivalent)/g dry weight (dw).

2.6. Sensory Evaluation of Cooked Pasta

The degree to which a consumer finds pasta acceptable is referred to as the pasta's sensory quality, with cooking serving as a tactical phase in the assessment of sensory attributes [40]. Using a 9-point hedonic scale [18], ten evaluators of both sexes and aged between 20–50 completed the sensory evaluation. They evaluated eight quality attributes: appearance, shape, texture, colour, smell, taste, stickiness, and chewing sensation. Pasta from each sample was cooked at the optimal cooking time, drained of excess water, and allowed to cool to room temperature. Then, the pasta was placed on white disposable plates and, along with the taster sheet, was randomly given to each assessor. The assessors received prior training on how to administer and finish the tasting sheet. Water was used to rinse the oral cavity in between each tasting.

2.7. Statistical Analysis

The results are reported as the mean ± standard deviation (SD) from three separate experiments. The statistical significance between samples was assessed using a one-way analysis of variance (ANOVA) and Tukey's multiple comparison test. The software GraphPad Prism (version 8.01) was used for this analysis. $p < 0.05$ was considered to be statistically significant.

3. Results and Discussion

The presence of egg in the pasta represents a key factor that affects the pasta's cooking parameters, colour, and texture, while offering additional nutritional advantages. In this study, five types of pasta were made with different concentrations of egg (0–100 g), but which also included wild garlic leaves, in a constant concentration in all variants (20 g). For this pasta, it was first observed how the amount of egg influences the pasta cooking parameters. Secondly, it was observed how the presence of *A. ursinum* L. influences both the cooking parameters and the presence of bioactive compounds with antioxidant capacity from the pasta. In the same manner, other types of pasta, containing different amounts of egg but no wild garlic, have been prepared.

3.1. Cooking Quality of Pasta

The duration of cooking is an important indicator in determining the quality of pasta for consumers. The optimal cooking time is influenced by the protein content of pasta. Gluten in pasta forms a strong matrix, and thus limits the access of water to the starch, which results in a longer starch gelation time. Our results have shown that increasing the amount of egg also increased the optimal cooking time. Thus, the cooking time almost doubled in the case of the Ctrl_5 variant, where the amount of egg was 100 g (Table 2) compared with Ctrl_1, without egg. On the other hand, the presence of wild garlic leaves led to a decrease in the cooking time, by an average of few seconds, compared with the control samples. Filipčev et al. (2023) also observed similar results in all pasta formulations using *A. ursinum* L. [2]. Overall, when pasta was enhanced with various vegetable sources, the results showed a reduction in OCT. This was mostly related to the dietary fibre content, which plays a role in the destruction of the protein network and accelerates up the starch's gelatinization [41]. On the other side, Teterycz et al. (2019) have shown that each additional egg increased the cooking time by enhancing the consistency of the protein starch structure. Adding one egg to a sample of common wheat flour increased the cooking time by one minute, and adding two eggs increased cooking time by two minutes [42].

Table 2. Cooking quality parameters of egg pasta enriched with wild garlic leaves.

Pasta Samples	OCT (Minutes)	SI	WA (%)	CL (%)
AU_1	4.50 ± 0.00 [d,e]	2.91 ± 0.04 [a]	225.50 ± 0.71 [a]	2.58 ± 0.0 [d,f]
AU_2	5.75 ± 0.35 [c,d,f]	2.73 ± 0.03 [a,b]	217.07 ± 2.92 [a]	2.56 ± 0.05 [d,f]
AU_3	6.50 ± 0.00 [b,c,f]	2.49 ± 0.06 [b]	202.71 ± 5.25 [b]	2.40 ± 0.01 [g]
AU_4	7.75 ± 0.35 [c,b]	2.29 ± 0.10 [b,c]	194.50 ± 7.78 [b,c]	2.07 ± 0.02 [h]
AU_5	9.40 ± 0.14 [a]	2.06 ± 0.08 [b,d]	196.37 ± 1.94 [b,d]	1.93 ± 0.02 [e,i]
Ctrl_1	4.75 ± 0.35 [e]	2.38 ± 0.06 [b,e]	190.67 ± 0.47 [b,e]	3.71 ± 0.05 [a]
Ctrl_2	6.00 ± 0.00 [e,f,g]	2.18 ± 0.04 [c,f]	185.05 ± 1.48 [b,f]	3.40 ± 0.01 [b]
Ctrl_3	6.70 ± 0.35 [c,g]	2.07 ± 0.09 [c,g]	180.14 ± 1.61 [e,f,g]	3.00 ± 0.01 [c]
Ctrl_4	8.25 ± 0.35 [a,b]	1.92 ± 0.09 [h]	172.77 ± 3.91 [f,h]	2.57 ± 0.04 [d]
Ctrl_5	9.50 ± 0.71 [a]	1.66 ± 0.04 [i]	171.08 ± 2.94 [f,i]	1.89 ± 0.00 [e]

Data are expressed as the mean ± SD (n = 3). Different letters superscripts in the same column indicate significant differences between the samples ($p < 0.05$). OCT—Optimal Cooking Time, SI—Swelling Index, WA—Water Absorption, CL—Cooking Loss; Ctrl_1, Ctrl_2, Ctrl_3, Ctrl_4, and Ctrl_5 represent experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg; AU_1, AU_2, AU_3, AU_4, and AU_5 represent experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg and a constant concentration of wild garlic (20 g).

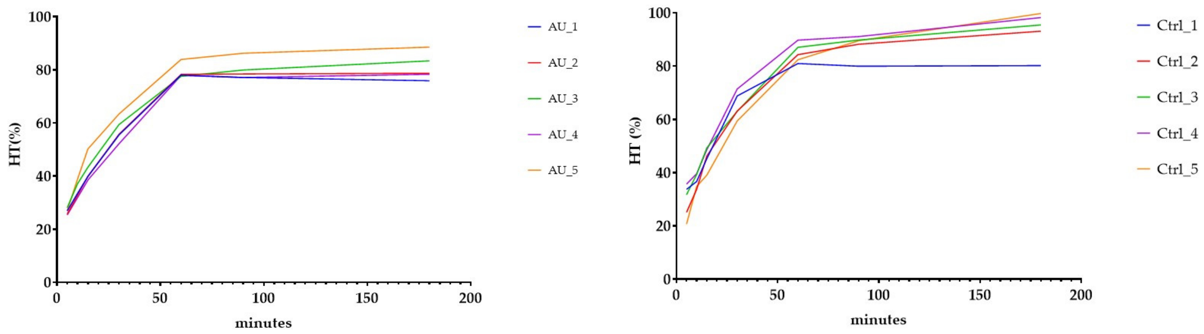
The SI index provides data on the extent to which the weight or volume of pasta increases during the cooking process. Our findings clearly show, that when the amount of egg in the pasta increases, the SI significantly decreases. This is probably of result of egg albumin coagulating and forming a stronger network with the gluten in the dough, which restricts water from passing through the pasta. Furthermore, the egg's lipid content generates a lipophilic condition that restricts the absorption of water by the starch.

The SI values of pasta, with or without wild garlic, decreased as the concentration of eggs increased. The lowest SI value of 1.66 ± 0.04 was observed in the Ctrl_5 sample (Table 2). On the other hand, the presence of wild garlic in the pasta resulted in a significantly increase in SI compared to the equivalent control egg pasta samples, probably due to the fact that wild garlic leaves allow water absorption. Filipčev et al. (2023) obtained comparable results when analysing pasta enriched with wild garlic powder [2]. The pasta showed low SI values compared to the control, but the amount of leaves powder did not significantly affect the SI value. The SI value was strongly correlated with WA (water absorption). The pasta with the highest egg content (Ctrl_5) recorded low values of both SI and WA (Table 2). The presence of wild garlic in the pasta resulted in a significantly increasing ($p < 0.05$) in water absorption compared to the corresponding control samples. The situation was also influenced by the amount of the egg, as an increase in its quantity results in a decrease in WA. The literature specifies that a higher water absorption suggests the presence of starch in higher amount, while a lower value represents a higher protein content [42]. However, in the study by Teterycz et al. (2019), the weight increase index value was increased for pasta to which the highest amount of egg was added [42]. In another study, Lambrecht et al. [43] showed that cooking properties, including water absorption, are influenced by the source of protein. Thus, the use of whole egg in noodles resulted in a decrease in WA, due to a stronger and tighter protein network that reduced the water absorption capacity, whereas the use of egg whites resulted in an increase in WA, due to albumin creating a weaker network.

In agreement with the literature, values between 150–200% for WA and a value of about 1.8 for SI are considered to be specific for quality pasta, without the addition of other ingredients [41].

The cooking loss (CL) parameter value was dependent on egg concentration. Increasing the amount of egg resulted in a decrease in solids loss during cooking. The highest CL value was recorded for the sample without egg, Ctrl_1 (3.71 ± 0.05%), and the lowest for the sample with the highest egg content (Ctrl_5) of 1.89 ± 0.00% (Table 2). The wild garlic pasta showed a similar trend, although the CL values ranged from 2.58 to 1.93%, which were less than the control pastas (Table 2). These findings corroborate those published by Porto Dalla Costa et al. (2016) [44], who emphasize that adding eggs to pasta that has been fortified with fibre leads to a more intricate protein network that inhibits solid footing. Pasta with a loss of up to 8% is deemed acceptable, according to the literature [41,42], and the pasta obtained in this study met this criterion.

The hydration test involves immersing dry pasta in water at a specific temperature, such as 25 °C, and measuring its weight at various time intervals. This test gives valuable information about the quality and characteristics of pastas. As shown in Figure 3, hydration of pastas occurs after 5 min, within a range of 25.10% and 20.70%, in the decreasing order of the amount of egg. In the case of pasta with wild garlic and egg, the hydration capacity had values between 25.38% and 28.14% after 5 min of hydration. After 60 min, the hydration plateau was reached. All of our pasta variations held their shape and did not crumble when put through the hydration test, indicating strong structural integrity, a crucial component of cooking qualities.



(**a**) (**b**)

Figure 3. Hydration test (HT) of raw pasta with wild garlic (**a**) and without wild garlic (**b**). Ctrl_1, Ctrl_2, Ctrl_3, Ctrl_4, and Ctrl_5 represent the experimental variants of egg pasta containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg; AU_1, AU_2, AU_3, AU_4, and AU_5 represent the experimental variants of egg pasta containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg and a constant concentration of wild garlic (20 g).

Thus, the cooking properties and quality of pasta are strongly influenced by the formation of covalent networks between proteins (gluten and egg albumin) and starch gelatinization [43].

Pasta is often a basic dish made with just two ingredients: flour and water. Starch, a type of carbohydrate, and gluten, a type of protein, are the two biopolymers found in flour. When exposed to water, the components of gluten—gliadin and glutenin—form a robust gluten network. Using mechanical and thermal energy, starch granules are dispersed throughout the protein network in the presence of water to create the pasta structure. To maintain the superior qualities of the dough, a compact, cross-linked structure produced by the gluten proteins is needed, which is stabilized by hydrogen bonds and hydrophobic interactions. When water is added to wheat flour and mixed together, the proteins take on an open structure, allowing hydration, swelling, and loosening of the bonds that hold the structure together [21]. Stretching the polymers under extensional stresses results in structural deformation and a decrease in covalent interactions. As a result, the disulfide bonds break and then re-establish, generating a network that is aligned in the direction of extension. The thickness of the sheets decreases and their interaction rises with an increase in mixing time. The gluten maintains the starch granules bound and placed in a well-developed protein matrix. Pasta is dried at the end of the process to reduce its moisture content under 12%. Three processes occur during pasta drying that cause the protein film to solidify: protein aggregation, polymerization, and denaturalization [21]. Water is simultaneously absorbed during cooking, creating an equilibrium between two mechanisms: protein hydration and coagulation and starch granule expansion and gelatinization. Good quality pasta is produced when protein coagulation succeeds in consolidating the protein matrix and trapping starch within it. Water then gradually permeates the network and gelatinization occurs. However, if starch swelling and solubilization are predominant, the gluten matrix tends to break down and release amylose into the cooking water, while amylopectin stays on the top and makes the pasta stickier [21].

Recently, attempts have been made to create novel pasta formulas that offer bioactive ingredients that are beneficial for human health in addition to necessary nutrients and energy [45]. Pasta's wheat flour is deficient in essential amino acids including methionine, lysine, and threonine, and has a protein content of only 10%. In order to complete the profile of necessary amino acids and proteins, exogenous proteins—like those from eggs—are added. Pasta made with egg albumin has a higher breaking strength and a better cooking tolerance, which reduces cooking losses [45]. Our results show that increasing the egg content in the pasta composition resulted in a significant decrease in CL ($p < 0.05$), but increased the optimal cooking time (Table 2). The functional qualities of the pasta, particularly its antioxidant capacity and polyphenol content, are enhanced by the addition of *A. ursinum* L. leaves. Further research is needed to fully understand the impacts of the interaction between the bioactive components in wild garlic and the proteins or lipids in pasta, which could have a result on cooking qualities and the exploration of oxidative stability.

3.2. Polyphenols and Antioxidant Capacity from Raw and Cooked Egg Pasta

The addition of wild garlic leaves ensured a source of polyphenols in the pastas. Table 3 shows the polyphenol content values of pasta variants with different egg concentrations, in parallel with the polyphenol content of cooked pasta.

Table 3. Total polyphenols content from raw and cooked egg pasta formulations.

	Raw Pasta				
	AU_1	**AU_2**	**AU_3**	**AU_4**	**AU_5**
TPh (µg GAE/g dw)	84.52 ± 2.36 [b]	82.44 ± 0.76 [b]	86.01 ± 2.017 [b]	90.00 ± 1.16 [a,b]	94.62 ± 0.83 [a]
FRAP (µmol TE/g dw)	124.56 ± 1.11 [b]	121.62 ± 2.10 [b]	124.82 ± 3.83 [b]	126.12 ± 3.09 [b]	158.12 ± 1.61 [a]
	Cooked Pasta				
TPh (µg GAE/g dw)	23.29 ± 0.70 [e]	26.43 ± 0.35 [d,e]	27.37 ± 0.70 [c,d]	36.05 ± 0.63 [b]	42.25 ± 1.46 [a]
FRAP (µmol TE/g dw)	25.44 ± 2.59 [b]	31.56 ± 2.10 [a,b]	38.94 ± 8.77 [a]	37.32 ± 0.74 [a,b]	38.76 ± 3.33 [a]

Data are expressed as the mean ± SD (n = 3). Different letters superscripts in the same line indicate significant differences between the samples ($p < 0.05$). TPh—Total polyphenols, FRAP—Ferric-Reducing Antioxidant Power. AU_1, AU_2, AU_3, AU_4, and AU_5 represent experimental egg pasta variants containing 0 g, 10 g, 10 g, 20 g, 50 g, and 100 g whole egg and a constant concentration of wild garlic leaves (20 g).

The amount of wild garlic leaves introduced in the pasta was constant in all experimental variants. The polyphenol concentration of fresh wild garlic leaves was found to be 1.99 ± 0.01 mg GAE/g fresh weight, while the polyphenol content of the pasta ranged from 82.44 to 94.62 µg GAE/g dw (Table 3), probably due to the fact that, although the same amount of wild garlic leaves was introduced, their distribution was uneven in the final product. The possibility that some amino acids (tryptophan, tyrosine, and cysteine) in the egg may react with the Folin–Ciocalteu phenol reagent suggests an additional explanation for an increase in overall phenol level, particularly in the pasta samples with high egg content [46]. Similar results were obtained by Vitali et al. (2020) [20], by the addition of asparagus flour in concentrations of 5, 10, 15, 20, and 25%, fortification which led to an increase in the polyphenol content in the raw pasta from 0.03 mg GAE/g pasta in the control sample to 3.25 mg GAE/g pasta in the sample with 25% asparagus flour concentration. The addition of 4% parsley flour results in an increase of polyphenol content in the raw pasta by 67% compared to the control [47].

The cooking process decreases the polyphenol content of pasta. This loss of polyphenols depends on the amount of egg added. Thus, the highest loss of phenols was recorded in the case of the AU_1 variant (without egg), i.e., 72.45%. The pasta with the highest amount of egg (AU_5) retained a higher amount of polyphenols, the loss being 55.35%. Similar results were obtained by Amoriello et al. (2022) [14], who added artichoke byproducts in the composition of pasta which led to increased phenolics content in raw pasta. Pasta fortified with artichoke byproducts lost 70% of its polyphenol content when it was cooked. Michalak-Majewska et al. (2020) [16], incorporated onion peel flour into pasta in percentages ranging from 2, 5, and 7.5 g/100 g flour, observing a slight increase in total phenolic content in both uncooked and cooked pasta, the highest amount having been found in pasta with 7.5% added onion flour, while the cooked control sample had almost halved polyphenol content.

Additionally, in other studies, it was found that cooking reduced the amount of phenolic compounds in pasta, although this was dependent on the pasta matrix [2,13]. Nevertheless, an increase in phenolic compounds was also noted in the literature [48] after cooking, most likely as a result of these compounds being extracted from the protein matrix more effectively.

The level of total polyphenols in enriched pasta has an influence on its antioxidant capacity. Also, the presence of sulphur compounds in wild garlic contributes to the antioxidant capacity of pasta enriched with *A. ursinum* L. The FRAP method was used to evaluate the antioxidant capacity of pasta fortified with the same amount of *A. ursinum* L. in all variants. In the case of raw pasta, the highest FRAP value was recorded in the case of the sample with the highest amount of egg, AU_5 (158.12 ± 1.61). Among the other pasta samples (AU_1–AU_4), there were no significant differences in terms of antioxidant capacity. On the other hand, during cooking, there is a loss of polyphenols in the cooking water, having consequences on the antioxidant properties, which recorded losses between 20.42% and 31.33%. The antioxidant capacity of uncooked pasta (AU_5) was significantly higher than that of the other samples. This could be related to the phenols and sulphur compounds in wild garlic, as well as the antioxidants lutein and zeaxanthin found in eggs [49].

3.3. Sensory Attributes Results of Pasta

Cooked pasta must meet consumer acceptability criteria. Therefore, consumer evaluation of sensory attributes is very important. Samples of cooked pasta were evaluated using a 9-point hedonic scale (9 corresponding to "Extremely pleasant" and 1 to "Extremely unpleasant"), by 10 raters who rated eight quality attributes: appearance, shape, texture, colour, smell, stickiness, and chewing sensation (Table 4).

Table 4. Sensory attributes of cooking egg pasta and egg pasta fortified with wild garlic.

Sample	Texture	Form	Appearance	Colour	Taste	Smell	Sticky	Chewing Sensation	Overall Quality
AU_1	7.30 ± 0.48 ^{b,c}	7.40 ± 0.84 ^{b,c}	7.50 ± 0.53 ^{b,c}	7.50 ± 0.53 ^{b,c}	7.30 ± 0.48 ^{b,c}	7.50 ± 0.85 ^{b,c}	7.30 ± 0.48 ^{b,c}	7.30 ± 0.67 ^{b,c}	7.39 ± 0.10 ^{b}
AU_2	8.20 ± 0.79 ^{a,b}	8.30 ± 0.67 ^{a,b}	8.20 ± 0.42 ^{a,b}	8.10 ± 0.57 ^{a,b}	8.10 ± 0.57 ^{a,b}	8.10 ± 0.74 ^{a,b}	8.10 ± 0.57 ^{a,b}	8.10 ± 0.57 ^{a,b}	8.15 ± 0.08 ^{a}
AU_3	8.10 ± 0.74 ^{a,b}	8.00 ± 0.67 ^{b,c}	8.10 ± 0.57 ^{a,b}	8.00 ± 0.67 ^{a,b}	8.00 ± 0.67 ^{a,b}	8.10 ± 0.57 ^{a,b}	8.00 ± 0.47 ^{a,b}	7.90 ± 0.57 ^{a,b}	8.03 ± 0.07 ^{a}
AU_4	7.60 ± 0.52 ^{b,c}	7.70 ± 0.48 ^{b,c}	7.80 ± 0.63 ^{b,c}	7.70 ± 0.48 ^{b,c}	7.80 ± 0.63 ^{b,c}	7.80 ± 0.63 ^{b,c}	7.70 ± 0.48 ^{b,c}	7.70 ± 0.48 ^{b,c}	7.73 ± 0.07 ^{f}
AU_5	7.50 ± 0.53 ^{b,c}	7.70 ± 0.67 ^{b,c}	7.70 ± 0.48 ^{b,c}	7.70 ± 0.67 ^{b,c}	7.50 ± 0.53 ^{b,c}	7.70 ± 0.67 ^{b,c}	7.60 ± 0.52 ^{b,c}	7.60 ± 0.52 ^{b,c}	7.63 ± 0.09 ^{c,f}
Ctrl_1	7.10 ± 0.57 ^{c}	7.20 ± 0.42 ^{c}	7.20 ± 0.63 ^{c,d}	7.10 ± 0.57 ^{c,d}	7.00 ± 0.67 ^{c,d}	7.10 ± 0.57 ^{c,d}	7.00 ± 0.67 ^{c,d}	7.10 ± 0.57 ^{c,d}	7.10 ± 0.08 ^{d}
Ctrl_2	7.80 ± 0.63 ^{b,c}	7.90 ± 0.74 ^{b,c}	7.80 ± 0.42 ^{b,c}	7.60 ± 0.52 ^{b,c}	7.80 ± 0.63 ^{b,c}	7.80 ± 0.63 ^{b,c}	7.80 ± 0.79 ^{b,c}	7.80 ± 0.63 ^{b,c}	7.79 ± 0.08 ^{e,f}
Ctrl_3	7.70 ± 0.67 ^{b,c}	7.60 ± 0.52 ^{b,c}	7.70 ± 0.48 ^{b,c}	7.50 ± 0.53 ^{b,c}	7.60 ± 0.52 ^{b,c}	7.70 ± 0.48 ^{b,c}	7.60 ± 0.52 ^{b,c}	7.60 ± 0.52 ^{b,c}	7.63 ± 0.07 ^{c,f}
Ctrl_4	7.30 ± 0.67 ^{b,c}	7.50 ± 0.53 ^{b,c}	7.60 ± 0.52 ^{b,c}	7.50 ± 0.53 ^{b,c}	7.40 ± 0.52 ^{b,c}	7.50 ± 0.53 ^{b,c}	7.50 ± 0.53 ^{b,c}	7.40 ± 0.52 ^{b,c}	7.46 ± 0.09 ^{b}
Ctrl_5	7.10 ± 0.57 ^{c}	7.40 ± 0.70 ^{b,c}	7.60 ± 0.52 ^{b,c}	7.50 ± 0.53 ^{b,c}	7.30 ± 0.67 ^{b,c}	7.40 ± 0.52 ^{b,c}	7.30 ± 0.82 ^{b,c}	7.20 ± 0.63 ^{b,c}	7.35 ± 0.16 ^{b}

Data are expressed as the mean ± SD (n = 10). Different letters superscripts in the same line indicate significant differences between the samples ($p < 0.05$). Ctrl_1, Ctrl_2, Ctrl_3, Ctrl_4, and Ctrl_5 represent the experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg; AU_1, AU_2, AU_3, AU_4, and AU_5 represent the experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg and a constant concentration of wild garlic leaves (20 g).

The mean scores obtained in the sensory evaluation of supplemented pasta, cooked at optimal time, are shown in Table 4. The results obtained vary between samples but also between the attributes analysed, with a difference between samples fortified (AU_1–AU_5) with wild garlic leaves and those with (Ctrl_2–Ctrl_5) or without egg (Ctrl_1). Thus, the consumers liked the pasta fortified with wild garlic leaves, with the five fortified variants recording the highest overall score compared to the control samples (Table 4). The AU_2 sample was the tasters' preferences with an overall score of 8.15 points, being classified in the very pleasant–extremely pleasant category. The absence or increase in egg concentration in cooked pasta indicates changes in the raters' preferences. The egg-free samples, AU_1 and Ctrl_1, had the lowest overall scores (7.39 and 7.13, respectively) and were categorized as pastas with pleasant sensory characteristics. With increasing egg concentration in the pasta (AU_3, AU_4, AU_5 and respectively Ctrl_3, Ctrl_4, Ctrl_5), tasters' preferences changed; some attributes improved (appearance, colour, stickiness), others were maintained (appearance, shape, smell, taste) and others depreciated (chewing sensation, texture), the evolution being different depending on the sample.

The addition of whole egg in high concentrations in the dough formation resulted in a firm product, the results evidenced by the mean scores of some quality attributes, the most affected being chew perception and texture. This firmness, according to Teterycz et al. 2019 [42], would be due to egg albumin, which is responsible for strengthening the protein matrix. However, the lipids contained in the egg interact with amylose during the cooking of pasta, which results in less loss of dry matter during cooking and less stickiness of cooked pasta. The colour of pasta improves with increasing egg yolk content because carotenoid pigments cause pasta to become more yellow [50].

In conclusion, the raters were able to differentiate between pasta samples, evaluating the quality attributes differently according to their perception and preference. The pasta with the lowest amount of egg (AU_2, with 10 g) fortified with wild garlic leaves was in the evaluators' preferences at a small distance from the pasta with wild garlic and 20 g egg concentration (AU_3). The egg-free pasta (Ctrl_1) received the lowest ratings in terms of texture, appearance, colour, stickiness, and perceived chewing sensation.

3.4. Estimated Nutritional Content of Pasta

Wild garlic has become increasingly appreciated in the food industry, due to the functional properties given by the bioactive compounds with potential therapeutic applications. The wild garlic's content in caloric nutrients is similar to the content observed in cultured garlic, the nutri-functional potential being given by the content in flavonoids and polyphenols with antioxidant properties [51].

The evaluation of the nutritional quality of the pasta with the addition of wild garlic compared to the pasta without wild garlic was carried out on the basis of the component ingredients of the pasta (Table 1). We also took into account the information taken from the databases and studies presented in the literature [8,52,53] from the USDA. The data presented in Table 5 allowed an evaluation of the quality of pasta with the addition of wild garlic compared to the quality of pasta without the addition of wild garlic. The aim was to highlight the nutri-functional properties of wild garlic with a view to incorporating it into some food products, which might ensure metabolic benefits in certain pathologies that are sensitive to the nutritional intake of biologically active macro- and micronutrients. The macro- and micronutrients identified in the pasta with added wild garlic highlighted that wild garlic could synergistically improve the functional capacity of the pasta where it can be found in different concentrations. The amount of protein identified in the pasta samples with the addition of wild garlic (Table 5) was influenced by the amount of egg added. The highest amount of protein was identified in AU_5 pasta (36.51 g), and the lowest amount of protein was identified in AU_1 pasta (23.95 g). In AU_4 pasta, the amount of protein was 30.23 g, 6.28 g lower compared to AU_5 pasta. The same situation was also observed in the pasta variants without the addition of wild garlic (Table 5), the highest amount of protein was recorded in Ctrl_5 (37.28 g) and the lowest amount of protein was recorded in Ctrl_1 (24.72 g).

Table 5. The estimated nutritional composition of pasta fortified with different amount of eggs and enriched with wild garlic leaves, reported at 100 g.

Pasta Samples	Protein (g)	Fat (g)	Carbohydrate (g)	E.V. (kcal)	ω_9 (g)	ω_6 (g)	ω_3 (g)	SFA (g)	TFA (g)	Chol. (mg)	Fibres (g)	Sugar (g)	Sodium (mg)
AU_1	7.033	0.662	51.24	245.093	0.056	0.266	0.015	0.105	0	0	1.873	0.562	2.349
AU_2	7.402	0.941	51.263	249.290	0.164	0.312	0.024	0.197	0.112	10.925	1.873	0.572	6.667
AU_3	7.772	1.221	51.284	253.486	0.271	0.359	0.034	0.029	0.0022	21.850	1.873	0.583	10.983
AU_4	8.878	2.059	51.348	26.607	0.594	0.498	0.061	0.564	0.0056	54.625	1.873	0.616	23.935
AU_5	10.722	3.455	51.453	287.058	1.131	0.731	0.107	0.102	0.011	109.251	0	1.874	45.521
Ctrl_1	7.259	0.690	53.779	256.686	0.061	0.276	0.016	0.109	0	0	1.903	0.190	1.468
Ctrl_2	7.628	0.970	53.800	260.883	0.169	0.322	0.025	0.201	0.001	10.925	1.903	0.201	5.786
Ctrl_3	7.997	1.249	53.822	265.079	0.276	0.368	0.034	0.293	0.002	21.85	1.903	0.212	10.103
Ctrl_4	9.104	2.087	53.88	277.669	0.598	0.508	0.061	0.568	0.006	54.625	1.903	0.245	23.054
Ctrl_5	10.948	3.484	53.991	298.651	1.136	0.741	0.107	1.027	0.011	109.251	1.903	0.298	44.640

E.V.—energy value, ω9—omega 9 monounsaturated fatty acids, ω6—omega 6 polyunsaturated fatty acids, ω3—omega 3 polyunsaturated fatty acids, SFA—saturated fatty acids, TFA—trans fatty acids, Chol.—Cholesterol; Ctrl_1, Ctrl_2, Ctrl_3, Ctrl_4, and Ctrl_5 represent the experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg; AU_1, AU_2, AU_3, AU_4, and AU_5 represent the experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg and a constant concentration of wild garlic (20 g).

The amount of carbohydrates was similar in the pasta variants with the addition of wild garlic (Table 1), the highest amount being recorded at AU_5 (175.2 g), providing 51.45 kcal/100 g and the lowest amount was recorded at AU_1 (174.48 g) without egg, providing 51.24 kcal/100 g. The results presented in Table 5 showed insignificant variations between the variants studied. In all variants where wild garlic was added, the amount of carbohydrates increased by 6.62 g, compared to the variants in which no wild garlic was added.

The amount of sugars was much higher in the pasta variants to which wild garlic was added, compared to the variants where wild garlic was not added, which attests that the addition of wild garlic leads to a sugar content that could improve the sensory properties of the pasta.

The Supplementary Table (Table S1) includes equations for calculating the nutritional quality indicators used to describe egg paste and egg paste enriched with wild garlic leaves.

Regarding the nutritional quality of pasta with added wild garlic, evaluated on the basis of lipid profile, it was observed that the atherogenic index (AtIa) [54] was 0.40 at AU_5 pasta (Table 6) where egg was added in the highest amount. The lowest value of atherogenic index (AtIa) was recorded at AU_1 where no egg was added. The value of this index increased proportional to the amount of egg added. With the exception of AU_5, where the atherogenic index was somewhat raised (0.40), compared to the recommended value of 0.39, all of the examined pasta varieties had an atherogenic index that was favourable to consumers' health requirements.

The HH ratio [54] is based on the fact that the fatty acids with a proinflammatory effect, myristic acid (C14:0), was poorly identified and palmitic acid (C16:0) was slightly increased, leading to an HH index of 3.358 for the AU_1 pasta and 2.572 for the AU_5 pasta (Table 6). The higher this index, the more favourable the anti-inflammatory effect will be to improve health status in some metabolic and nutritional pathologies. In the variants without added wild garlic (Table 6), the HH ratio was similar to the HH ratio observed in the pasta variants with wild garlic, but somewhat higher, 3.378 in Ctrl_1 and 2.579 in Ctrl_5. All pasta variants without the addition of wild garlic showed a higher HH ratio compared to the variants where wild garlic was added.

The synergistic metabolic effect could also be supported by the PUFAs/SFAs ratio (Table 6), which was shown to have values of 0.800 in AU_1 pasta with added wild garlic and 0.782 in Ctrl_1 pasta without added wild garlic. The lowest values of PUFAs/SFAs ratios for both the variants with and without added wild garlic were 0.241 for AU_5 and 0.242 for Ctrl_5, respectively. The higher this ratio, the more favourable the health impact of fatty acid consumption, showing functional activity.

Table 6. Evolution of nutritional quality indicators for pasta with different egg concentrations, and with and without wild garlic leaves reported to the 100 g.

Pasta Samples	AtIa	HH	HPI	PUFAs/SFAs	UFAs/SFAs
AU_1	0.09	0.990	0.990	0.800	0.940
AU_2	0.10	0.880	0.870	0.500	0.747
AU_3	0.11	0.834	0.814	0.425	0.719
AU_4	0.11	0.782	0757	0.291	0.60
AU_5	0.12	0.755	0.728	0.241	0.565
Ctrl_1	0.09	0.992	0.992	0.782	0.947
Ctrl_2	0.10	0.890	0.871	0.510	0.753
Ctrl_3	0.10	0.840	0.820	0.404	0.680
Ctrl_4	0.11	0.785	0.760	0.294	0.604
Ctrl_5	0.12	0.757	0.730	0.242	0.567

HH—ratio of hypocholesterolemic/hypercholesterolemic fatty acids; AtIa—atherogenic index; HPI—health promotion index; PUFAs/SFAs—ratio of polyunsaturated fatty acids to saturated fatty acids; UFAs/SFAs—ratio of unsaturated fatty acids to saturated fatty acids. Ctrl_1, Ctrl_2, Ctrl_3, Ctrl_4, and Ctrl_5 represent the experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg; AU_1, AU_2, AU_3, AU_4, and AU_5 represent the experimental egg pasta variants containing 0 g, 10 g, 20 g, 50 g, and 100 g whole egg and a constant concentration of wild garlic (20 g).

The health promotion index (HPI) [55] is the ratio of the amount of unsaturated fat to the amount of saturated fat (C12:0; C14:0, C16:0) and is currently used mainly in research on the nutritional quality of food products, with values ranging from 0.782 to 0.800.

Wild garlic has also been used to formulate different types of foods because of its biological qualities and flavour. Dicu et al. (2022), for example, produced an emulsified meat product by incorporating powdered wild garlic leaf and chestnut flour (*Castanea sativa* Mill.) in varying amounts. This study demonstrated the impact of addition on the nutritional value, fat content, and shelf life of the reformulated meat products [56]. Ivanova et al. (2023) performed a similar study and included wild garlic to the recipe for meat-cut semi-finished products [57]. Dairy products have also been enriched with wild garlic. Pluta-Kubic et al. (2022) found that adding wild garlic leaves to soft cow milk rennet-curd cheese improved both the sensory qualities and volatile acid profile [58]. Znamirowska et al. (2017) showed that adding 1% concentration of *A. ursinum* L. powder can be used as a supplement to change the flavour and taste of kefir [59]. Šobot et al. (2019) concluded that addition of osmodehydrated wild garlic to biscuit dough formulation has provided better biscuits texture analysis results and changed colour characteristics in comparison to the fresh wild garlic addition [60]. Following the determination of nutritional and sensory attributes, cookies improved with osmohydrated wild garlic leaves in molasses were superior compared to the control, according to another recent study [61].

Based on our research, we have shown that wild garlic can be successfully used in pasta. Additionally, this process serves as a means of preserving the *A. ursinum* L., allowing it to be used all year round despite its short vegetation period (about 4 months/year) [24]. One aspect which may be a limiting factor in the use of wild garlic leaves in pasta is the colour. Some consumers only accept the classic yellow colour for pasta, but others might associate the green colour of pasta with healthy natural ingredients. One limitation of our research would be that people with egg allergies are unable to eat pasta that contains eggs, which would restrict the study's participant group. Considering the increasing demand for wild garlic products, it is crucial to implement careful management strategies to prevent excessive harvesting and promote sustainable practices.

Wild garlic has a potent antibacterial action, as demonstrated by the literature [62–64], therefore it can be utilized to prolong food products' shelf life in place of synthetic food additives.

4. Conclusions

This study set out to evaluate the quality of both cooked and uncooked pasta that had been enhanced by adding wild garlic leaves to pasta recipes that had different egg concentrations. According to our findings, adding wild garlic leaves to egg pasta improves a number of nutritional parameters and raises the amount of polyphenols in both raw and cooked pasta. The ability of pasta to retain its bioactive ingredients is limited by cooking. On the other hand, adding eggs in varying amounts preserves the higher level of polyphenols in cooked pasta. The addition of wild garlic leaves has little effect on the technological parameters of cooking; instead, the greater the influence, the firmer the resultant egg concentration. In terms of taste, pasta with garlic flavour and the least amount of egg was the most favoured. Pasta using wild garlic has the potential to benefit the food sector as well as the health of consumers. Pasta enriched with wild garlic and eggs can be classified as a functional food because it contains both nutrient-rich ingredients and bioactive compounds that may provide certain health benefits.

This study therefore provides a quick premise for enriching pasta with fresh leaves from wild flora. However, more studies are needed to improve the technological parameters and to find solutions for keeping as many phytonutrients as possible in the pasta.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app14177517/s1, Table S1: The nutritional quality indicators and equations used in their calculation.

Author Contributions: Conceptualization, S.I.V. and C.A.R.; methodology, S.I.V., C.A.R. and M.A.G.; validation, A.C.T., M.A.G. and M.F.B.; formal analysis, M.A.G.; investigation, C.A.R., A.C.T. and M.F.B.; resources, S.I.V.; writing—original draft preparation, C.A.R. and M.F.B.; writing—review and editing, C.A.R. and S.I.V.; supervision, S.I.V.; project administration, C.A.R. and M.A.G.; funding acquisition, C.A.R. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article and Supplementary Materials, further inquiries can be directed to the corresponding author.

Acknowledgments: This research was supported by the University of Oradea, within the Grants Competition "Scientific Research of Excellence Related to Priority Areas with Capitalization through Technology Transfer: INO—TRANSFER—UO—2nd Edition", Project No. 237/2022.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Cappelli, A.; Cini, E. Challenges and Opportunities in Wheat Flour, Pasta, Bread, and Bakery Product Production Chains: A Systematic Review of Innovations and Improvement Strategies to Increase Sustainability, Productivity, and Product Quality. *Sustainability* **2021**, *13*, 2608. [CrossRef]
2. Filipčev, B.; Kojić, J.; Miljanić, J.; Šimurina, O.; Stupar, A.; Škrobot, D.; Travičić, V.; Pojić, M. Wild Garlic (*Allium ursinum*) Preparations in the Design of Novel Functional Pasta. *Foods* **2023**, *12*, 4376. [CrossRef] [PubMed]
3. Biernacka, B.; Dziki, D.; Różyło, R.; Gawlik-Dziki, U. Banana Powder as an Additive to Common Wheat Pasta. *Foods* **2020**, *9*, 53. [CrossRef] [PubMed]
4. Elaborado, P.; Rivadeneira, R.M. *Revisión Bibliográfica Sobre El Cáñamo y la Pasta*; ResearchGate: Berlin, Germany, 2024. [CrossRef]
5. International Pasta Organisation. Available online: https://internationalpasta.org/about-ipo/ (accessed on 21 July 2024).
6. Muresan, C.C.; Farcas, A.; Man, S.; Suharoschi, R.; Vlaic, R.A. Obtaining a Functional Product Through the Exploitation of Mushroom Flour in Pasta. *BUASVMCN-FST* **2017**, *74*, 17. [CrossRef]
7. Troccoli, A.; Borrelli, G.M.; De Vita, P.; Fares, C.; Di Fonzo, N. Mini Review: Durum Wheat Quality: A Multidisciplinary Concept. *J. Cereal Sci.* **2000**, *32*, 99–113. [CrossRef]
8. FoodData Central. Available online: https://fdc.nal.usda.gov/ (accessed on 30 July 2024).
9. Teterycz, D.; Sobota, A.; Zarzycki, P.; Latoch, A. Legume Flour as a Natural Colouring Component in Pasta Production. *J. Food Sci. Technol.* **2020**, *57*, 301–309. [CrossRef]

10. Alamprese, C. The Use of Egg and Egg Products in Pasta Production. In *Egg Innovations and Strategies for Improvements*; Elsevier: Amsterdam, The Netherlands, 2017; pp. 251–259, ISBN 978-0-12-800879-9.
11. Gallo, M.; Ferrara, L.; Calogero, A.; Montesano, D.; Naviglio, D. Relationships between Food and Diseases: What to Know to Ensure Food Safety. *Food Res. Int.* **2020**, *137*, 109414. [CrossRef]
12. Nguyen, T.Q.N.; Nguyen, P.H.; Vo, M.T.; Le, V.V.M. Utilizing Sweet Corn "Milk" Residue to Develop Fiber-Rich Pasta: Effects of Replacement Ratio and Transglutaminase Treatment on Pasta Quality. *J. Food Process. Preserv.* **2024**, *2024*, 5853459. [CrossRef]
13. García-Moncayo, A.I.; Rodríguez-Martínez, E.S.; Ochoa-Reyes, E.; Sáenz-Hidalgo, H.K.; Sepúlveda, D.R.; Buenrostro-Figueroa, J.J.; Alvarado-González, M. Nutritionally Improved Pasta with Arthrospira Platensis: Effect of Cooking on Antioxidant Capacity and Pigments Content. *Emir. J. Food Agric.* **2023**, *35*, 782–790. [CrossRef]
14. Amoriello, T.; Mellara, F.; Ruggeri, S.; Ciorba, R.; Ceccarelli, D.; Ciccoritti, R. Artichoke By-Products Valorization for Phenols-Enriched Fresh Egg Pasta: A Sustainable Food Design Project. *Sustainability* **2022**, *14*, 14778. [CrossRef]
15. Choudhary, P.; Devi, T.B.; Tushir, S.; Kasana, R.C.; Popatrao, D.S.; Narsaiah, N. Mango Seed Kernel: A Bountiful Source of Nutritional and Bioactive Compounds. *Food Bioprocess. Technol.* **2023**, *16*, 289–312. [CrossRef]
16. Michalak-Majewska, M.; Teterycz, D.; Muszyński, S.; Radzki, W.; Sykut-Domańska, E. Influence of Onion Skin Powder on Nutritional and Quality Attributes of Wheat Pasta. *PLoS ONE* **2020**, *15*, e0227942. [CrossRef]
17. Wang, J.; Brennan, M.A.; Brennan, C.S.; Serventi, L. Effect of Vegetable Juice, Puree, and Pomace on Chemical and Technological Quality of Fresh Pasta. *Foods* **2021**, *10*, 1931. [CrossRef] [PubMed]
18. Rekha, M.N.; Chauhan, A.S.; Prabhasankar, P.; Ramteke, R.S.; Rao, G.V. Influence of Vegetable Purees on Quality Attributes of Pastas Made from Bread Wheat *(T. aestivum)*. *CyTA J. Food* **2013**, *11*, 142–149. [CrossRef]
19. Minarovičová, L.; Lauková, M.; Kohajdová, Z.; Karovičová, J.; Dobrovická, D.; Kuchtová, V. Qualitative Properties of Pasta Enriched with Celery Root and Sugar Beet By-Products. *Czech J. Food Sci.* **2018**, *36*, 66–72. [CrossRef]
20. Vital, A.C.P.; Itoda, C.; Crepaldi, Y.S.; Saraiva, B.R.; Matumoto-Pintro, P.T. Use of Asparagus Flour from Non-Commercial Plants (Residue) for Functional Pasta Production: Asparagus Flour for Functional Pasta Production. *J. Food Sci. Technol.* **2020**, *57*, 2926–2933. [CrossRef] [PubMed]
21. Bustos, M.C.; Perez, G.T.; Leon, A.E. Structure and Quality of Pasta Enriched with Functional Ingredients. *RSC Adv.* **2015**, *5*, 30780–30792. [CrossRef]
22. Błażewicz-Woźniak, M. The Impact of Selected Agrotechnical Treatments on the Growth of Wild Garlic (*Allium ursinum* L.) Leaves in Field Cultivation. *Acta Sci. Pol. Hortorum Cultus* **2023**, *22*, 81–91. [CrossRef]
23. Rosan, C.; Bei, M.; Heredea, R.; Vicas, S. Influence of Various Treatments on the Level of Photosynthetic Pigments, Bioactive Compounds and Antioxidant Potential in *Allium ursinum* L. Leaves. *Nat. Resour. Sustain. Dev.* **2024**, *14*, 99–110. [CrossRef]
24. Sobolewska, D.; Podolak, I.; Makowska-Wąs, J. *Allium ursinum*: Botanical, Phytochemical and Pharmacological Overview. *Phytochem. Rev.* **2015**, *14*, 81–97. [CrossRef]
25. Kovačević, T.K.; Major, N.; Sivec, M.; Horvat, D.; Krpan, M.; Hruškar, M.; Ban, D.; Išić, N.; Goreta Ban, S. Phenolic Content, Amino Acids, Volatile Compounds, Antioxidant Capacity, and Their Relationship in Wild Garlic (*A. ursinum* L.). *Foods* **2023**, *12*, 2110. [CrossRef] [PubMed]
26. Andjic, M.; Novakovic, J.; Kocovic, A.; Nikolic, M.; Petrovic, A.; Jakovljevic, V.; Bradić, J. The Effects of Chronic Administration of *Allium ursinum* Extract on Systemic Redox Status in Rats. In Proceedings of the 2nd International Symposium on Biotechnology; Faculty of Agronomy in Čačak, University of Kragujevac, Čačak, Serbia, 4–5 March 2024; pp. 587–592.
27. Barbu, I.A.; Ciorîță, A.; Carpa, R.; Moț, A.C.; Butiuc-Keul, A.; Pârvu, M. Phytochemical Characterization and Antimicrobial Activity of Several Allium Extracts. *Molecules* **2023**, *28*, 3980. [CrossRef] [PubMed]
28. Kovarovič, J. Evaluation and Comparison of Total Polyphenols Content and Antioxidant Activity of Wild Garlic (*Allium ursinum* L.) in Selected Morphological Parts. *JMBFS* **2019**, *9*, 492–495. [CrossRef]
29. Krivokapic, M.; Bradic, J.; Petkovic, A.; Popovic, M. Phytochemical and Pharmacological Properties of *Allium ursinum*. *Serb. J. Exp. Clin. Res.* **2021**, *22*, 357–362. [CrossRef]
30. Lachowicz, S.; Kolniak-Ostek, J.; Oszmiański, J.; Wiśniewski, R. Comparison of Phenolic Content and Antioxidant Capacity of Bear Garlic (*Allium ursinum* L.) in Different Maturity Stages: Phenolics and Antioxidants in Bear Garlic. *J. Food Process. Preserv.* **2017**, *41*, e12921. [CrossRef]
31. Stanisavljević, N.; Soković Bajić, S.; Jovanović, Ž.; Matić, I.; Tolinački, M.; Popović, D.; Popović, N.; Terzić-Vidojević, A.; Golić, N.; Beškoski, V.; et al. Antioxidant and Antiproliferative Activity of *Allium ursinum* and Their Associated Microbiota During Simulated In Vitro Digestion in the Presence of Food Matrix. *Front. Microbiol.* **2020**, *11*, 601616. [CrossRef]
32. Chetrariu, A.; Dabija, A. Quality Characteristics of Spelt Pasta Enriched with Spent Grain. *Agronomy* **2021**, *11*, 1824. [CrossRef]
33. Osorio-Díaz, P.; Islas-Hernández, J.J.; Agama-Acevedo, E.; Rodríguez-Ambriz, S.L.; Sánchez-Pardo, M.E.; Bello-Pérez, L.A. Chemical, Starch Digestibility and Sensory Characteristics of Durum Wheat/Unripe Whole Banana Flour Blends for Spaghetti Formulation. *Food Nutr. Res.* **2014**, *5*, 264–270. [CrossRef]
34. Gopalakrishnan, J.; Menon, R.; Padmaja, G.; Sajeev, M.S.; Moorthy, S.N. Nutritional and Functional Characteristics of Protein-Fortified Pasta from Sweet Potato. *Food Nutr. Sci.* **2011**, *02*, 944–955. [CrossRef]
35. Jambrec, D.; Sakač, M.; Mišan, A.; Mandić, A.; Pestorić, M. Effect of Autoclaving and Cooking on Phenolic Compounds in Buckwheat-Enriched Whole Wheat Tagliatelle. *J. Cereal Sci.* **2015**, *66*, 1–9. [CrossRef]

36. Singleton, V.L.; Orthofer, R.; Lamuela-Raventós, R.M. Analysis of Total Phenols and Other Oxidation Substrates and Antioxidants by Means of Folin-Ciocalteu Reagent. In *Methods Enzymol*; Oxidants and Antioxidants Part A; Academic Press: Cambridge, MA, USA, 1999; Volume 299, pp. 152–178.
37. Vicas, S.; Prokisch, J.; Rugina, O.D.; Socaciu, C. Hydrophilic and Lipophilic Antioxidant Activities of Mistletoe (Viscum Album) as Determined by FRAP Method. *Not. Bot. Horti Agrobot. Cluj-Napoca* **2009**, *37*, 112–116.
38. Benzie, I.F.; Strain, J.J. The Ferric Reducing Ability of Plasma (FRAP) as a Measure of "Antioxidant Power": The FRAP Assay. *Anal. Biochem.* **1996**, *239*, 70–76. [CrossRef]
39. Miere, F.; Teuşdea, A.; Vasile, L.; Luminita, F.; Moldovan, L.; Costea, T.; Uivarosan, D.; Vicaş, S.; Pallag, A. Natural Polymeric Beads for Encapsulation of Stellaria Media Extract with Antioxidant Properties. *Mater. Plast.* **2019**, *56*, 671. [CrossRef]
40. Marti, A.; D'Egidio, M.G.; Pagani, M.A. Pasta: Quality Testing Methods. In *Encyclopedia of Food Grains*; Elsevier: Amsterdam, The Netherlands, 2016; pp. 161–165, ISBN 978-0-12-394786-4.
41. Bianchi, F.; Tolve, R.; Rainero, G.; Bordiga, M.; Brennan, C.S.; Simonato, B. Technological, Nutritional and Sensory Properties of Pasta Fortified with Agro-industrial By-products: A Review. *Int. J. Food Sci. Technol.* **2021**, *56*, 4356–4366. [CrossRef]
42. Teterycz, D.; Sobota, A.; Kozłowicz, K.; Zarzycki, P. Substitution of Semolina Durum with Common Wheat Flour in Egg and Eggless Pasta. *Acta Sci. Pol. Technol. Aliment.* **2019**, *18*, 439–451. [CrossRef] [PubMed]
43. Lambrecht, M.A.; Rombouts, I.; Nivelle, M.A.; Delcour, J.A. The Role of Wheat and Egg Constituents in the Formation of a Covalent and Non-covalent Protein Network in Fresh and Cooked Egg Noodles. *J. Food Sci.* **2017**, *82*, 24–35. [CrossRef]
44. Porto Dalla Costa, A.; Cruz Silveira Thys, R.; De Oliveira Rios, A.; Hickmann Flôres, S. Carrot Flour from Minimally Processed Residue as Substitute of β-Carotene Commercial in Dry Pasta Prepared with Common Wheat (*Triticum aestivum*). *J. Food Qual.* **2016**, *39*, 590–598. [CrossRef]
45. Li, M.; Zhu, K.; Guo, X.; Brijs, K.; Zhou, H. Natural Additives in Wheat-Based Pasta and Noodle Products: Opportunities for Enhanced Nutritional and Functional Properties. *Comp. Rev. Food Sci. Food Safe* **2014**, *13*, 347–357. [CrossRef]
46. Everette, J.D.; Bryant, Q.M.; Green, A.M.; Abbey, Y.A.; Wangila, G.W.; Walker, R.B. Thorough Study of Reactivity of Various Compound Classes toward the Folin−Ciocalteu Reagent. *J. Agric. Food Chem.* **2010**, *58*, 8139–8144. [CrossRef]
47. Sęczyk, Ł.; Świeca, M.; Gawlik-Dziki, U.; Luty, M.; Czyż, J. Effect of Fortification with Parsley (*Petroselinumcrispum* Mill.) Leaves on the Nutraceutical and Nutritional Quality of Wheat Pasta. *Food Chem.* **2016**, *190*, 419–428. [CrossRef]
48. Rocchetti, G.; Lucini, L.; Chiodelli, G.; Giuberti, G.; Montesano, D.; Masoero, F.; Trevisan, M. Impact of Boiling on Free and Bound Phenolic Profile and Antioxidant Activity of Commercial Gluten-Free Pasta. *Food Res. Int.* **2017**, *100*, 69–77. [CrossRef] [PubMed]
49. Di Marco, F.; Trevisani, F.; Vignolini, P.; Urciuoli, S.; Salonia, A.; Montorsi, F.; Romani, A.; Vago, R.; Bettiga, A. Preliminary Study on Pasta Samples Characterized in Antioxidant Compounds and Their Biological Activity on Kidney Cells. *Nutrients* **2021**, *13*, 1131. [CrossRef] [PubMed]
50. Miranda, J.; Anton, X.; Redondo-Valbuena, C.; Roca-Saavedra, P.; Rodriguez, J.; Lamas, A.; Franco, C.; Cepeda, A. Egg and Egg-Derived Foods: Effects on Human Health and Use as Functional Foods. *Nutrients* **2015**, *7*, 706–729. [CrossRef] [PubMed]
51. Hussein, W.I.; Faizy, H.S.; Youssef, S.M.A. Nutritional Values and Phytochemical Analysis of *Allium calocephalum* Wendelbo, a Valuable Endemic Wild Garlic to Zagros Mountains. *Bionatura* **2022**, *7*, 17. [CrossRef]
52. Oosthuizen, C.B.; Reid, A.-M.; Lall, N. Garlic (*Allium sativum*) and Its Associated Molecules, as Medicine. In *Medicinal Plants for Holistic Health and Well-Being*; Lall, N., Ed.; Academic Press: Cambridge, MA, USA, 2018; pp. 277–295, ISBN 978-0-12-812475-8.
53. Tavares, L.; Santos, L.; Zapata Noreña, C.P. Bioactive Compounds of Garlic: A Comprehensive Review of Encapsulation Technologies, Characterization of the Encapsulated Garlic Compounds and Their Industrial Applicability. *Trends Food Sci. Technol.* **2021**, *114*, 232–244. [CrossRef]
54. Ulbricht, T.L.V.; Southgate, D.A.T. Coronary Heart Disease: Seven Dietary Factors. *Lancet* **1991**, *338*, 985–992. [CrossRef]
55. Chen, J.; Liu, H. Nutritional Indices for Assessing Fatty Acids: A Mini-Review. *Int. J. Mol. Sci.* **2020**, *21*, 5695. [CrossRef]
56. Dicu, A.M.; Perța-Crișan, S.; Rotar, I.M.; Ursachi, C.Ș. Reformulated Meat Product with Wild Garlic and Chestnut Flour. *J. Agroaliment. Process. Technol.* **2022**, *28*, 89–95.
57. Ivanova, G.; Kolman, O.; Glotova, M.; Nikulina, E.; Evtukhova, O. Development of New Recipes for Minced Meat Semi-Finished Products Using *Allium ursinum*. *E3S Web Conf.* **2023**, *443*, 02002. [CrossRef]
58. Pluta-Kubica, A.; Najgebauer-Lejko, D.; Domagała, J.; Štefániková, J.; Golian, J. The Effect of Cow Breed and Wild Garlic Leaves (*Allium ursinum* L.) on the Sensory Quality, Volatile Compounds, and Physical Properties of Unripened Soft Rennet-Curd Cheese. *Foods* **2022**, *11*, 3948. [CrossRef]
59. Znamirowska, A.; Szajnar, K.; Rożek, P.; Kalicka, D.; Kuźniar, P.; Hanus, P.; Kotula, K.; Obirek, M.; Kluz, M. Effect of Addition of Wild Garlic (*Allium ursinum*) on the Quality of Kefirs from Sheep's Milk. *Acta Sci. Pol. Technol. Aliment.* **2017**, *16*, 209–215. [CrossRef]
60. Šobot, K.; Laličić-Petronijević, J.; Filipović, V.; Nićetin, M.; Filipović, J.; Popović, L. Contribution of Osmotically Dehydrated Wild Garlic on Biscuits' Quality Parameters. *Period. Polytech. Chem. Eng.* **2019**, *63*, 499–507. [CrossRef]
61. Filipović, V.; Nićetin, M.; Filipović, J.; Stupar, A.; Kojić, J.; Lončarević, I.; Šobot, K.; Laličić-Petronijević, J. Evaluation of Cookies Enriched with Osmodehydrated Wild Garlic from Nutritional and Sensory Aspects. *Foods* **2024**, *13*, 1941. [CrossRef]
62. Burton, G.P.; Prescott, T.A.K.; Fang, R.; Lee, M.A. Regional Variation in the Antibacterial Activity of a Wild Plant, Wild Garlic (*Allium ursinum* L.). *Plant Physiol. Biochem.* **2023**, *202*, 107959. [CrossRef] [PubMed]

63. O'Gara, E.A.; Hill, D.J.; Maslin, D.J. Activities of Garlic Oil, Garlic Powder, and Their Diallyl Constituents against *Helicobacter Pylori*. *Appl. Environ. Microbiol.* **2000**, *66*, 2269–2273. [CrossRef] [PubMed]
64. Harris, J.C.; Cottrell, S.L.; Plummer, S.; Lloyd, D. Antimicrobial Properties of *Allium sativum* (Garlic). *Appl. Microbiol. Biotechnol.* **2001**, *57*, 282–286. [CrossRef] [PubMed]