Fakulta zemědělská a technologická
Faculty of Agriculture and Technology

Jihočeská univerzita v Českých Budějovicích
University of South Bohemia in České Budějovice

UNIVERSITY OF SOUTH BOHEMIA IN ČESKÉ BUDĚJOVICE
FACULTY OF AGRICULTURE AND TECHNOLOGY

Department of Plant Production

Master Thesis

Possibilities of Using Buckwheat in the Production of Functional Pasta

Author: Oladele Mayowa Nojeem

Supervisor: doc. Ing. Jana Pexová Kalinová, Ph.D.

České Budějovice
2023

Declaration

I declare that I am the author of this graduation thesis and that I used only sources and literature displayed in the list of references in its preparation.

In České Budějovice on ....

Signature

Abstrakt

Pohanka setá má velký potenciál pro další využití ve funkčních potravinách díky značnému obsahu biologicky aktivních látek. Hledají se proto další možnosti jejího využití v potravinách s cílem obohatit lidskou výživu o tyto látky. Cílem této práce bylo otestovat možnost výroby těstovin s různým podílem mouky z pohankových klíčků a zhodnotit jejich vybrané kvalitativní vlastnosti. Práce zahrnuje kvalitativní a senzorické hodnocení semolinových těstovin obsahujících různé podíly mouky z pohankových klíčků a pohankových microgreens (0-20 %). Hodnoceny byly následující parametry: optimální doba vaření, absorpce vody, ztráty během vaření, přilnavost těstovin jejich barva, celkový vzhled, povrch, pružnost, průsvitnost, chuť, vůně a celkový dojem. Pro výrobu těstovin lze doporučit použití mouky z pohankových klíčků v podílu 10 %.

Klíčová slova: těstoviny; pohanka; microgreens; klíčky; senzorické hodocení

Abstract

Common buckwheat has a high potential for further use in functional foods due to the significant content of biologically active substances. Therefore, other possibilities of using buckwheat in food are searched in order to enrich human nutrition with the beneficial compounds. The aim of this work was to test the possibility of pasta production with different proportions of buckwheat sprouts and evaluate their selected qualitative properties. The work includes qualitative and sensory evaluation of semolina pasta containing different proportions of flour from buckwheat sprouts and buckwheat microgreens (0-20%). The following parameters were evaluated: optimal cooking time, cooking water absorption, swelling, cooking loss, adhesion, color, overall look, surface, flexibility, translucency, flavour, taste, the overall impression. For the production of pasta, it is recommended to use buckwheat sprouts flour in the portion of 10 %.

Keywords: pasta; buckwheat; microgreens; sprout; sensory evaluation

Acknowledgment

I am deeply grateful to my supervisor, doc. Ing. Jana Pexova Kalinova Ph.D. whose encouragement, guidance and constant support from the beginning of this thesis to the end. Her expertise and patience have been invaluable to me and have played a crucial role in the success of this thesis.

THANK YOU FOR EVERYTHING

Content

Introduction ... 7

1 Literary Review ... 9

1.1 Taxonomy of Buckwheat ... 9

1.2 Production of Buckwheat ... 10

1.3 Nutritional Value and Composition of Buckwheat ... 11

1.4 Sprouts and Microgreens ... 16

1.4.1 Buckwheat Sprouts and Microgreens ... 21

1.4.2 Food Fortification with Sprouts and Microgreens ... 24

2 Aim of the Thesis ... 27

3 Material and Methods ... 28

4 Results ... 33

5 Discussion ... 41

Conclusions ... 43

References ... 44

List of Figures ... 50

List of tables ... 52

Image Attachment ... 53

Introduction

Buckwheat is one of the oldest plant species originating from Asia. It was cultivated in China thousands of years ago, but it has not found its place in the large-scale agricultural production, yet. However, in recent years, buckwheat has been gaining importance due to greater requirements for plants that provide organic (healthy and safe) food.

Buckwheat is used as a subsistence crop in many of the more mountainous areas. It is a thermophilic and has quite low requirements for the environment conditions. Although, it has serious requirements for water, and is able to get water even from greater deep. Buckwheat is able to get nutrients even from forms that are less accessible or not accessible at all for the other crops due to its highly active root system.

Buckwheat has also low requirements for crop rotation systems due to it may be grown as the last crop in the crop rotation and it can be cultivated under reduces tillage or no till farming systems. Buckwheat may be grown as an intercrop or a cover crop. Buckwheat reduces the risk of occurrence of Fusaria or other pathogens in the subsequent crop; and also suppresses the weed growth.

The crop is not a cereal, but the seeds (strictly achenes) are usually classified among the cereal grains because of their similar usage. The grain is generally used as human food and as animal or poultry feed, with the de-hulled groats being cooked as porridge and the flour used in the preparation of pancakes, biscuits, noodles, cereals, etc. The crop produces also honey with high antioxidant potential. The flowers and green leaves are used for rutin extraction for use in medicine and the small leaves and shoots are used as leafy vegetables. This, coupled with the plant’s ability to do well on poorer soils, probably accounts for its multipurpose usage.

Due to the significant content of biologically active substances, buckwheat also has a high potential for further use in functional foods. Functional foods are those that exert a scientifically proven specific health benefit (health claim) beyond their nutritional properties, although the consumption of its specific formulation is not essential for human life. The buckwheat-enriched products has to a wide range of biological and healthy activities: hypocholesterolemic, hypoglycemic, anticancer, anti-inflammatory etc. Therefore, an effort is being made to suggest other possibilities of application of buckwheat in food in order to enrich human nutrition with the beneficial effects attributed to buckwheat.

1 Literary Review

1.1 Taxonomy of Buckwheat

Kingdom: Plantae
Phylum (Division): Magnoliophyta (Flowering plants)
Class: Magnoliopsida (Dicotyledons)
Order: Caryophyllales
Family: Polygonaceae
Genus: Fagopyrum

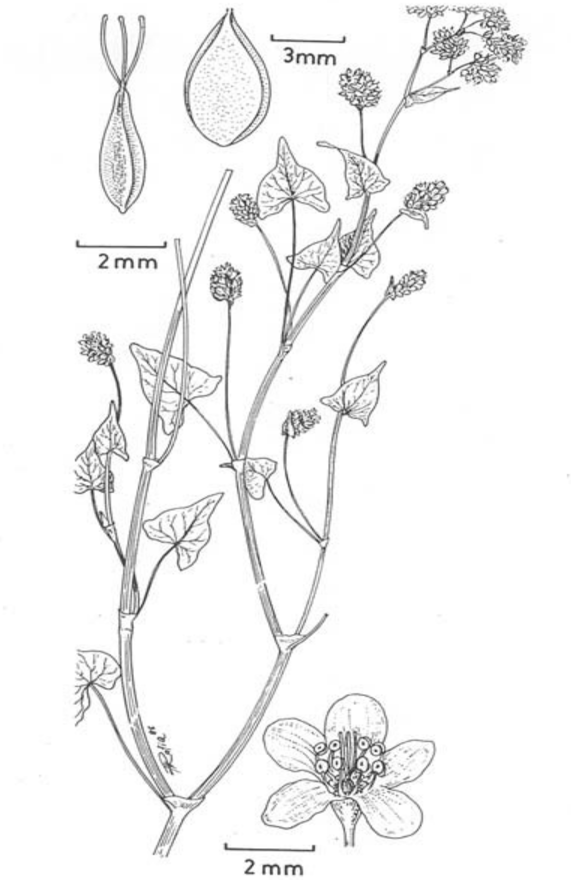


Figure 1.1: ***Fagopyrum esculenthum*** **(Efloras.org 2022)**

Fagopyrum is a genus including less than 30 herbaceous species, mostly endemic to southern China. *Fagopyrum* is clearly distinguished from other genus in Polygonaceae by the central position of embryo in achene. The genus includes two cultivated species, common buckwheat *Fagopyrum esculentum* Moench and Tartary buckwheat *Fagopyrum tataricum* L. Both species are annual plants (Ohsako and Li 2020).

Common buckwheat (Figure 1.1) is a fast growing heterostylous diploid species with an indeterminate growth. It is a broadleaved plant, with a smooth, succulent generally green stalk, a knotted single main stem that develops lateral branches. The main stem is grooved. Plant height varies from 30 to 120 cm. The stems are hollow, with a diameter of 3 to 15 mm. The plants have a short root, penetrating to a depth of 30 to 50 cm. The leaves are petiolate, heart shaped, ovate-triangular to triangular, 4 to 8 cm long. The blades are hairless (Campbell 1997; Jansen 2006). Flowers are heterostylous, obligate out-crosser pink or red, pedicelled, about 1 mm across. Achenes are deeply 3-angled, brown, smooth, narrowed at both the ends, 4-8 × 2.5-5 mm broad. Plants are flowering June-August and fruiting: July – September (Gondola and Papp 2010). Both common and tartary buckwheat were born in southern China (mountain areas of China, Bhutan, northern India, and Nepal (Ohnishi 1992).

1.2 Production of Buckwheat

In Europe, common buckwheat is traditionally cultivated and widely used in Russia, Ukraine, Belarus, Poland, the Czech Republic, northern Croatia, Slovenia, Austria, Denmark and north-western France (Michalová 2003). Common buckwheat grown in Europe accounts for 50% of world production, see Figure 1.2 (FAOSTAT 2022)

Total world production of common buckwheat achenes in 2020 was estimated to be 1.80 million tons from 1.86 million ha and the main producers were the Russian Federation, China, Ukraine and France (FAOSTAT 2022).

Tartary buckwheat is grown traditionally in adjacent areas of Belgium and Germany, Slovenia, Italy, Bosnia and Herzegovina as well as in a mixed crop with common buckwheat. Recently, it was reported that more than 100 hectares of Tartary buckwheat are grown annually in Värmland, Sweden (Kreft et al. 2020). Tartary buckwheat shows greater cold resistance than common buckwheat, and has traits for drought tolerance (Campbell 2003).

Common buckwheat is traditional crop in the Czech Republic, that is important for organic agriculture where it is one of most often growing crops (Michalová 2003). In recent years, there is a demand for this crop mainly as a medicinal plant for its high content of rutin and other polyphenols and also because of its suitability for the production of functional foods (Michalová 2000).

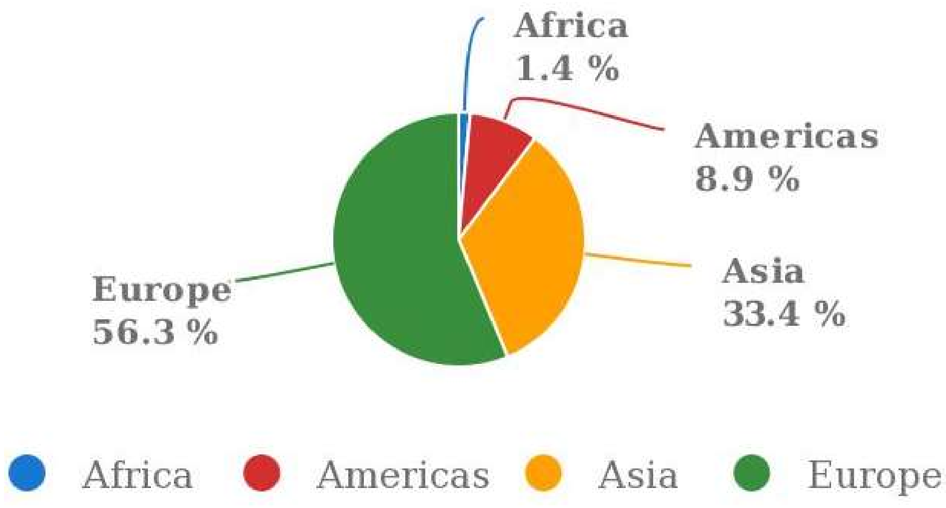


Figure 1.2: Production share of common buckwheat by region in 2020 (FAOSTAT 2022)

1.3 Nutritional Value and Composition of Buckwheat

The nutritional value of buckwheat is considerably higher than that of many other grains (Table 1.1). The total content of components depends on the variety or environmental factors (Bárta et al. 2004).

Table 1.1: Chemical composition (% dry matter basis) of tartary and common buckwheat (Bonafaccia & Fabjan 2003)

Buckwheat	Protein	Ash	Fat	Fiber		
				Soluble	Insoluble	Total
Common	11.0	2.6	3.4	1.2	5.3	6.5
Tartary	10.3	1.8	2.5	0.5	5.8	6.3

Protein

Because of its well-balanced amino acid profile, the protein in buckwheat is very high quality. It is particularly rich in the amino acids lysine and arginine (Table 1.2 and 1.3) (Sytar et al. 2018).

Table 1.2: Essential amino acid composition of buckwheat and other cereals (% of protein) (Campbell 1997)

Food grain	Lysine	Methionine	Tryptophan	Leucine
Buckwheat	5.9	3.7	1.4	5.8
Amaranth	5.0	4.4	1.4	4.7
Wheat	2.6	3.5	1.2	6.3
Rice	3.8	3.0	1.0	8.2
Maize	1.9	3.2	0.6	13.0
FAO/WHO recommendation	5.5	3.5	1.0	7.0

Table 1.3: Amino acid composition of proteins from the grains of common buckwheat (mean ± standard deviation on dry weight basis) (Sytar et al. 2018).

Amino acids	Content [g·kg⁻¹]	
	F. esculentum var. Rubra	*F. esculentum* var. Karadag
Non-essential amino acids		
Alanine	8.87 + 0.23	6.38 + 0.46
Aspartic acid	15.59 + 0.46	14.98 + 1.42
Cysteine	3.85 + 0.03	3.30 + 0.03
Glutamic acid	36.46 + 0.29	31.94 + 2.84
Glycine	9.61 + 0.30	8.57 + 0.52
Proline	5.39 + 0.50	5.38 + 0.52
Tyrosine	4.26 + 0.45	3.62 + 0.54
Serine	9.11 + 2.78	8.16 + 0.57
Essential amino acids		
Threonine	7.13 + 0.65	6.48 + 0.53
Valine	6.40 + 0.16	5.83 + 0.40
Isoleucine	5.23 + 0.42	4.82 + 0.28
Leucine	11.12 + 0.40	10.24 + 0.19
Phenylalanine	7.25 + 0.30	6.71 + 0.54
Lysine	9.07 + 1.14	7.96 + 0.35
Methionine	1.88 + 0.18	1.69 + 0.02
Semi-essential amino acids		
Arginine	15.57 + 0.01	13.64 + 0.43
Histidine	4.91 + 0.50	4.64 + 0.44
Sum of amino acids	161.7 + 8.80	144.34 + 10.08

The protein content in buckwheat was approximately 12% and thus very much the same as in wheat. However, due to the high contents of crude fiber and tannin, the true protein digestibility was slightly below 80% (Eggum et al. 1980).

Like other pseudocereals, buckwheat is gluten-free and therefore suitable for people with gluten intolerance. Buckwheat protein consists of 18.2% albumin, 43.3% globulin, 0.8% prolamin, 22.7% glutelin, and 5.0% other nitrogen residue (Javornik and Kreft, 1984).

Buckwheat grain protein can reduce cholesterol levels in serum. According to Ma and Xiong (2009), digestion-resistant peptides are largely responsible for bile acid elimination. These effects are most probably connected with the limited digestibility of buckwheat grain protein.

Carbohydrates

The main carbohydrate of buckwheat is starch, which makes up 51-70% weight of the achene (Michalová and Čejka, 1997). However, buckwheat has less digestible starch than wheat (48% heat - treated buckwheat, 50% white wheat bread) (Skrabanja et al., 1998). The groat contains resistant starch, which is resistant to digestion and is thus categorized as fiber. Resistant starch is fermented by gut bacteria in your colon. These beneficial bacteria produce short-chain fatty acids (SCFAs), such as butyrate. Butyrate and other SCFAs serve as nutrition for the cells lining your colon, improving gut health and decreasing your risk of colon cancer. Some of the soluble carbohydrates in buckwheat, such as fagopyritol and D-chiro-inositol, have been shown to help moderate the rise in blood sugar after meals (Hosaka et al. 2011).

Buckwheat scores low to medium on the glycemic index (GI) — a measure of how quickly a food raises blood sugar after a meal — and should not cause unhealthy spikes in blood sugar levels (Skrabanja et al. 2001). This means that it should be safe to eat for most people with diabetes type 2 diabetes. The lower blood sugar in people with diabetes after buckwheat consumption is also due to the unique compounds D-chiro-inositols (Steadman et al. 2001)

Fiber

The whole achene of buckwheat contains 7% total dietary fiber. This nutrient is good for colon health. Fiber is concentrated in the husk. The husk is kept in dark buckwheat flour, giving it a unique flavor. By weight, fiber makes up 2.7% of boiled groats and is mainly composed of cellulose and lignin.

Buckwheat bran is a rich source of total dietary fiber and soluble dietary fibre, particularly bran without hull fragments has 16% total dietary fiber of which 75% is soluble dietary fibre (Steadman et al. 2001).

Fat

In common buckwheat there is a prevalence of unsaturated fatty acids – C18:1, C18:2, C18:3 and C20:1 (Bonafaccia et al., 2003). Unsaturated fatty acids make up 82% fat, of which 32% is polyunsaturated (Becker, 1994). The main acid is palmitic and linoleic acid (Mazza, 1986).

Minerals and vitamins

Buckwheat is richer in minerals than many common cereals, such as rice, wheat, and corn. Buckwheat is reach especially in manganese, copper, and magnesium (Table 4). Compared to other grains, the minerals in cooked buckwheat groats are particularly well absorbed (Marshall 1982).

However, buckwheat is not particularly high in vitamins (Table 1.4). Buckwheat flour contains various vitamins, such as B1, B2, and niacin, at relatively high levels (Pomeranz, 1983).

Table 1.4: Average mineral and vitamin contents of buckwheat (Marshall 1982)

Mineral	Content (mg/100 g)	Vitamin	Content (mg/1000 g)
Calcium	110	Thiamine	3.3
Iron	4	Riboflavin	10.6
Magnesium	390	Pantothenic acid	11.0
Phosphorus	330	Choline	440
Potassium	450	Niacin	18.0
Copper	0.95	Pyridoxine	1.5
Manganese	3.37	Tocopherols	40.0
Zinc	0.87		

Flavonoids

Buckwheat is rich in various antioxidant plant compounds, which are responsible for many of its health benefits (lower risk of cancer and heart disease). In fact, it provides more antioxidants than many other cereal grains, such as barley, oats, wheat, and rye. Its plant compounds include rutin, quercetin, vitexin and othres (Luthar et al. 2021).

Rutin, an antioxidant that may cut the risk of heart disease by preventing the formation of blood clots and decreasing inflammation and blood pressure, is the main antioxidant in buckwheat (Table 5), rutin may lower the risk of cancer and improve inflammation, blood pressur and blood lipid profile (Park et al. 2004).

The seed coat is rich in epicatechin (257.60 mg/kg), procyanidin B2 (118.6 mg/kg), and epicatechin gallate (61.27 mg/kg). The embryo axis with the cotyledons is rich in rutin (283.37 mg/kg) and catechin (161.41 mg/kg). Contrary to groats, vanillic acid, vanillin, vitexin, quercitrin, and protocatechuic acid were detected in the buckwheat hulls (Kalinová et al. 2019).

Table 1.5: The rutin content (mg /100g) in common buckwheat (Park et al., 2004)

Flowers	Leaves	Stems	Roots	Achenes
372.8	115.6	17.4	10.1	22.6

Buckwheat in Human Nutrition

Buckwheat can provide health benefits due to its contents of resistant starch, mineral elements, proteins, and in particular, phenolic substances, which prevent the effects of several chronic human diseases, including hypertension, obesity, cardiovascular diseases, and gallstone formation. Buckwheat achenes are processed into groats, flour, and noodles. The groats, used in much the same way as rice, are the main ingredient in many traditional European and Asian dishes (Luthar et al. 2021).

1.4 Sprouts and Microgreens

Based on size or age of salad crop categories, sprouts are the youngest and smallest, microgreens are slightly larger and older (usually 5-10 cm tall). Microgreens are vegetable harvested and sold just after the cotyledon leaves have developed, at the first true leaf stage. Time from seeding to harvest can vary greatly by crop from 7 to 21 days (Treadwell et al. 2020).

Microgreens are produced from the seeds of vegetables, cereals or herbs. Common microgreens are grown mainly from cabbage (*Brassicca oleracea*), beet (*Beta vugaris*), kale (*Brassicca oleracea*, *Acephala* group), kohlrabi, (*Brassicca oleracea Gongylodes* group), mustard (*Brassicca rapa* var. *paviridis*,) radish (*Raphanus sativus* L.), Swiss chard (*Beta vulgaris*), broccoli (*Brassica oleracea* convar. *botrytis* var *italica*) and amaranth (*Amaranthus lividus*) see Figure 1.3. As many as 80–100 crops and crop varieties have reportedly been used as microgreens (Treadwell et al. 2020).

Microgreens are specific type of vegetable (Figure 1.3). They are used as a nutrition supplement, a visual enhancement, and a flavour and texture enhancement of food. Microgreens are used to enhance the color, or to garnish a wide variety of main dishes. Microgreens can add sweetness and spiciness to foods (Wojdyło et al. 2020).

Figure 1.3: A variety of crops can be grown as microgreens (Treadwell et al. 2020)

Microgreens production began at the end of 1980s (Kyriacou et al. 2016), and their popularity as functional foods has been constantly gaining [Choe and Wang 2018].

Despite their higher price, the demand for these vegetables is significant. The global microgreens market is expected to reach a market size of US$17,039.744 million in 2025 from US$10,936.914 million in 2019. Broccoli play an most imperative role in the growth of the microgreen market. The total global production of Broccoli as microgreens was around 26 million metric tonnes in 2017 (Anonym 2021). Vertical Farming has an indispensable role in the growth of the microgreens market in the coming years due to the rising global population and surging urbanization (Anonym 2021). The highest microgreens market was in 2020 in United States, Canada, Asia and Australia, see Figure 1.4 (Paraschivu et al. 2021).

Microgreens can be produced in the garden, pot, tray as well as container. Containerized production allow for commercialization of the product while growing on the media, to be harvested directly by the end user. Harvested microgreens are highly washed, cooled as soon as possible using good handling practices for food safety (Figure 1.5). Microgreens are generally packed in polyethylene packages and cooled to recommended temperatures before supplying to the market or consumers (Murphy et al. 2010). The life cycle of microgreens is very short, because they quickly deteriorate after harvest (Wojdyło et al. 2020).

Figure 1.4: Microgreens Market: market size, by region in 2020 (Mordor Intelligence Platform 2020)

For sprouting, plant species in the Poaceae, Brassicaceae, and Fabaceae families are most exploited (Galieni et al. 2020). The most commonly consumed sprout varieties are alfalfa, mung bean, red clover, radish, broccoli and wheat grass. Although sprouts have been a diet staple in Chinese culture for over 5,000 years, they remained relatively unpopular in other countries. Approximately 80 million pounds of alfalfa seed and 15-20 million pounds of mung beans are produced each year in the United States (Food Source Information 2022). The sprout production proces is shown in Figure 1.5.

So, sprouts and microgreens can be produced quickly, easily, and cost-effectively due to simple requirements for equipment and supplies, and a rapid developmental process. This suggests a unique opportunity for industrial production coupled with the prospect for consumers to independently access food with nutritional benefits (Galieni et al. 2020).

Sprouts and microgreens are considered "functional foods", because are rich in vitamins, minerals, and antioxidants (MicroGreensUSA, 2009; Brentlinger 2007). They have been found to contain higher levels of biologically active compounds than found in mature plants or seeds (Janovská et al. 2010).

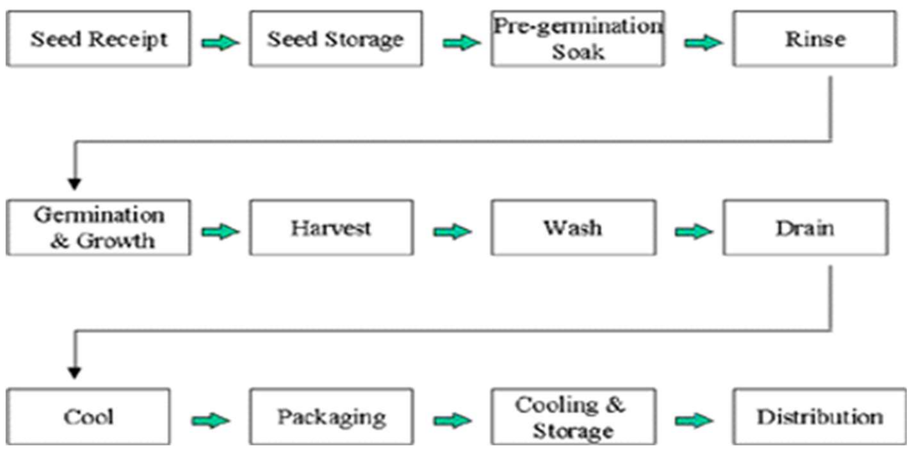


Figure 1.5: Sprout production proccess (FDA, 1999)

E.g. broccoli sprouts and microgreens have higher contents of bioactive compounds and potential antioxidants and exhibit higher anti-inflammatory and anticancer activities compared to their corresponding adult plants (Moreira-Rodríguez, 2017).

Sprouts generally contain high levels of folate, magnesium, phosphorus, and vitamin K. E.g. High concentration of ascorbic acid was found in red cabbage microgreens (Xiao et al. 2012). 50 times more sulfurophane was found in Broccoli microgreens by weight than mature broccoli (Xiao et al. 2015).

Additionally, sprouts are better sources of amino acids, pectins and sugars than microgreens. Microgreens were characterized by high content of carotenoids and chlorophylls, and organic acid, without any sugars, exhibiting higher anti-diabetic and anticholinergic activity than sprouts (Wojdyło et al. 2020).

Compared to seeds or mature plants, both sprouts and microgreens are known to contain low amounts of antinutrients, while being rich in amino acids, fatty acids, and simple sugars as a result of enzymatic breakdown of large macromolecules, and phytochemicals (Galieni et al. 2020).

Nutritional and functional importance of microgreens according to Sharma et al. (2022) are summarized on Figure 1.6.

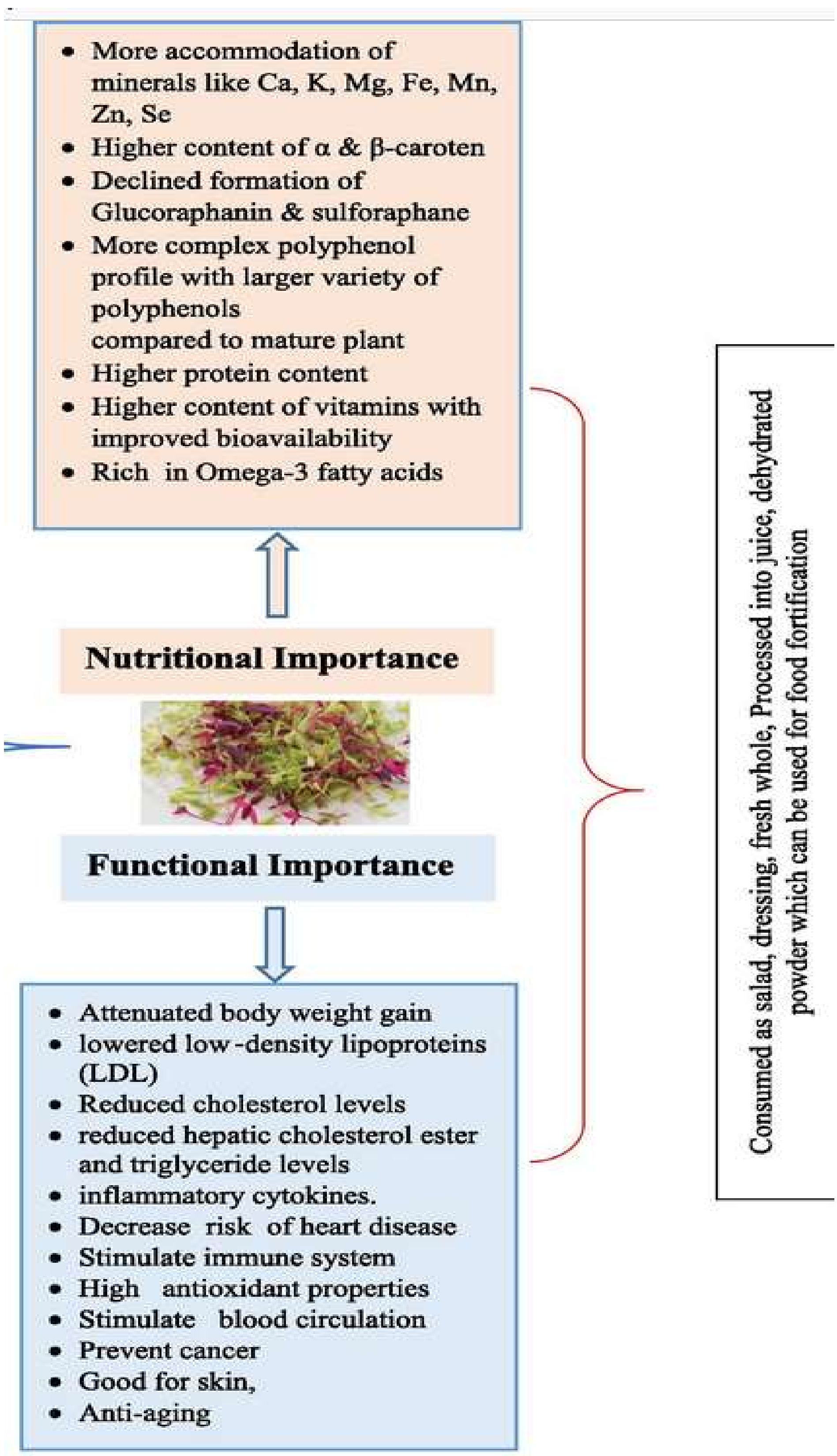


Figure 1.6: Nutritional and functional importance of microgrrens according to Sharma et al., (2022).

1.4.1 Buckwheat Sprouts and Microgreens

Buckwheat sprouts have a soft and slightly crispy texture and an attractive fragrance, but do not have beany flavour as soybean sprouts do. Buckwheat sprouts have a light-yellow color (Figure 1.6 a). By using the mass production system (Figure 1.7), approximately 8.9 kg of buckwheat sprouts were harvested from the 1.0 kg of buckwheat seeds. Pericarp shedding rate is one of the important quality related characteristics of buckwheat sprouts because the pericarp-remained sprouts are not only difficult to be removed, but also to become an obstacle in using them as fresh vegetables (Kim e t al. 2004)

Figure 1.7: Buckwheat sprouts (a) and production system(b, c) (Kim e t al. 2004)

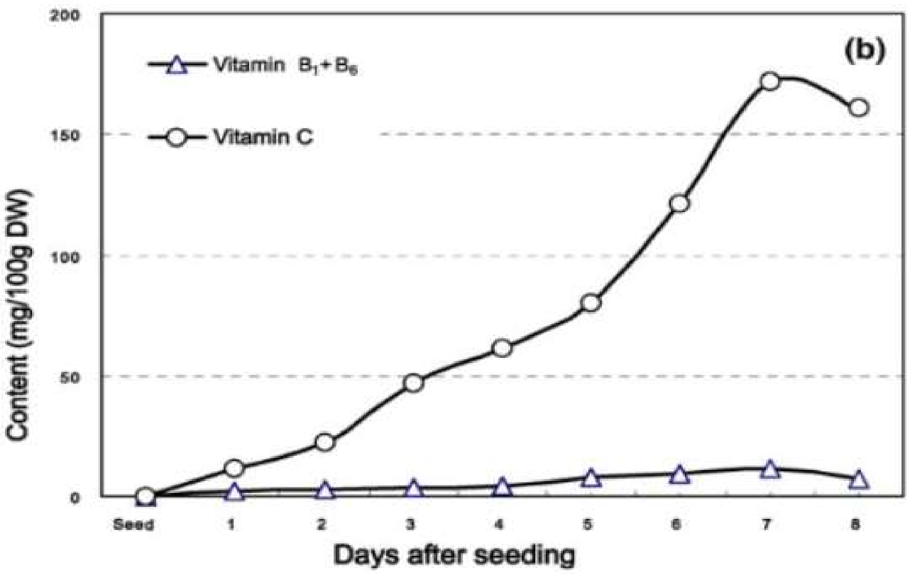


Figure 1.8: Changes of vitamin B1+B6 and vitamin C contents in buckwheat sprouts according to days after seeding (Kim e t al. 2004)

Buckwheat sprouts are abundant in amino acids, minerals, and crude fiber. The lysine content of buckwheat sprouts were notably higher than those of buckwheat seeds and other cereals. Moreover the rutin contents of buckwheat sprouts were higher than those of buckwheat seeds. The total amino acid contents of buckwheat sprouts (acid hydrolysis with 6 N HCl) were approximately 28–38% higher than those of buckwheat seeds, and that 14 kinds of amino acids were notably increase. Also a significant increase in the content of vitamins especially vitamin C and B (Figure 1.8) in buckwheat sprouts has been described (Kim et al. 2001).

Crude ash contents of buckwheat microgreens grown under white, red, and blue light were 0.39%, 0.31%, and 0.37%, respectively. Crude protein contents of buckwheat microgreens grown under red, white, and blue light were 7.81%, 1.60%, and 2.40%, respectively. Crude fat contents of buckwheat microgreens grown under blue, red, and white light were 1.12%, 0.54%, 0.35%, and 0.22%, respectively. Vitamin C content was the highest (104.3 mg/kg) in microgreens grown under white light and the lowest under blue light (54.3 mg/kg). For mineral content measurement of buckwheat microgreens, Ca, K, Mg, and P contents were high whereas B, Cu, and Zn contents were not detected (Choi et al. 2015).

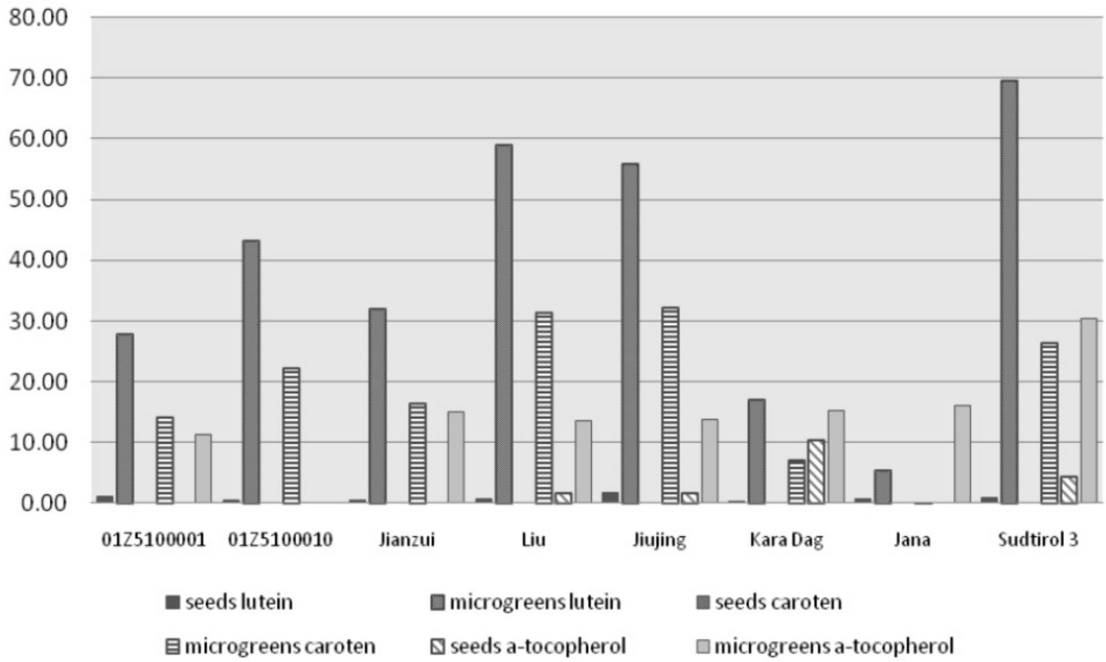


Figure 1.9: Carotenooids and alfa-tocopherol in common and tartary microgreens (ug.g-1 dm) (Janovská et al. 2010)

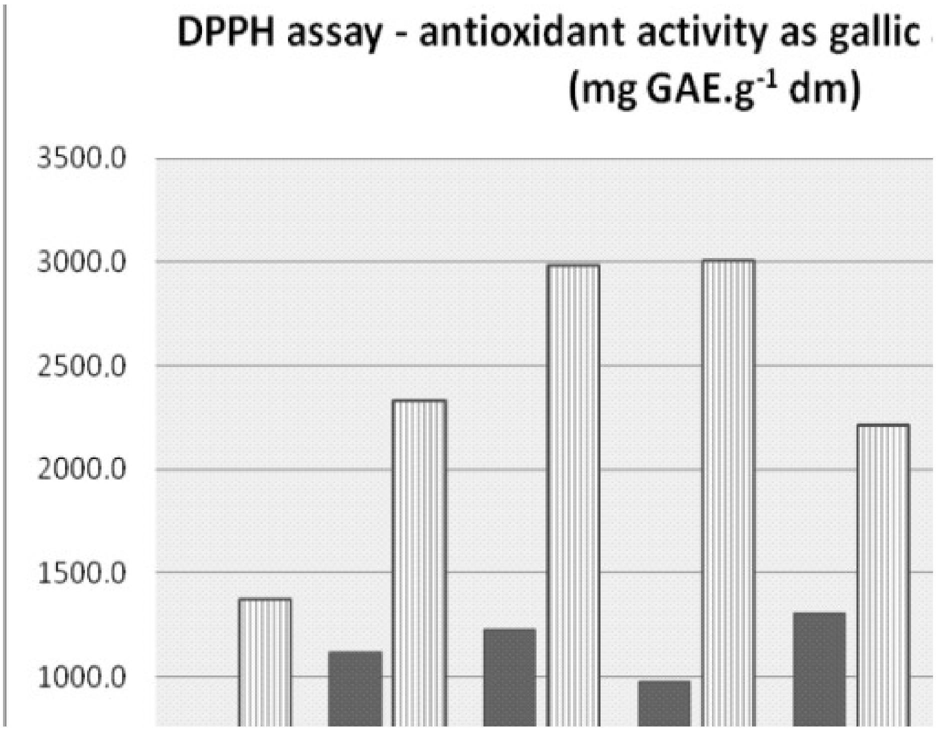


Figure 1.10: Antioxidant activity (DPPH assay) of different varieties of common buckwheat - seeds and microgreens comparison (mg galic acid equivalent . g^{-1} DM) (Janovská et al. 2010)

Buckwheat microgreens specifically are high in antioxidants, flavonoids, carotenoids, and α-tocopherol contents see Figure 1.9 (Janovská et al. 2010). Buckwheat microgreens also showed higher antioxidant activity than buckwheat achenes see Figure 1.10 (Janovská et al. 2010)

In the hypocotyl and cotyledons of five cultivars of common buckwheat sprouts and microgreens trans-cinnamic acid and its derivatives: o-, m, and p-coumaric acids (2-, 3-, and 4-hydroxycinnamic), synapic acid (4-hydroxy-3,5-dimethoxycinnamic), caffeic acid (3,4-dihydroxycinnamic), and two isomers of ferulic acid (4-hydroxy-3-methoxycinnamic and 3-hydroxy-4-methoxycinnamic) have been identified. Among the benzoic acid derivatives hydroxybenzoic, protocatechuic (3,4-dihydroxybenzoic), gallic (3,4,5-dihydroxybenzoic) and syringic (4-hydroxy-3,5-dimethoxybenzoic) were found in the organs (Wiczkowski 2016).

1.4.2 Food Fortification with Sprouts and Microgreens

Fortification is the incorporation of bioactive compounds within a food matrix to prevent specific nutrient deficiencies and promote population health (Dwyer et al., 2015). Bread is a frequently and highly consumed grain product in almost all types of Western diets. Therefore, bread could be a suitable product to fortify with health-promoting secondary plant metabolites. Bread-fortification were generally verified by the addition of lyophilized plant powder or purified substances. An alternative to adding such bread ingredients is to use microgreens (Klopsch et al. 2018).

Sprouts or microgreens can be used in other areas, e.g. in dairy products. Nanopowered peanut sprouts could potentially be used as a prebiotic and potential source of dietary antioxidants in the cheese. Thiobarbituric acid values of the cheese were significantly decreased when nanopowdered peanut sprout was added into the production of Caciocavallo-like cheese (Ko et al. 2017).

Sprouted grains or microgreens is also possible used in many other staple foods such as pasta, noodles, and breakfast flakes, but food processing often compromises their nutritional value (Ebert 2022).

1.5 Pasta Production and Their Importance

Pasta is made comprising of wheat flour and water or eggs. Pasta are types of food made from unleavened dough, which is rolled flat and cut, stretched, A wide variety of pasta is available in the market (EMR 2023). Pasta can be dried, frozen, chilled, and canned, that can offer save time for meal preparation. Pasta can be prepared with various sauces so that it is suited to the palates of almost every culture (Mordorintelligence.com 2023).

About 14.3 million tons of pasta are produced annually worldwide, especially in Italy, the United States, Brazil, Turkey, and Russia. Italians are the also main pasta consumers, with 23.1 kg per capita per year (IPO 2014). Only durum semolina can assure the best product quality, in terms of dough rheological properties, cooking quality and consumer acceptance (Sissons 2008).

The global pasta market size reached a value of about USD 25.67 billion in 2022. The pasta market is further expected to increase and 2028 to reach a value of approximately USD 31.14 billion by 2028. Europe is expected to lead the global pasta market in the coming years due to increased consumption rate. The Asia is also likely to witness fast growth in the coming years due to increasing demand from China, Japan, and India (EMR2023) On the other hand, the consumption of linguini, fettuccini, spaghetti pasta, and noodles increased significantly during the pandemic. The consumers stockpiled products with higher shelf life. The market and stocks were replenished on time, which reflected a strong sales of these products during the pandemic (Mordorintelligence.com 2023).

WHO (the World Health Organization) and FAO (the Food and Agriculture Organization of the United Nations) described pasta as a healthy, sustainable, and quality food model. Moreover, in 2010, UNESCO (United Nations Educational, Scientific and Cultural Organization) declared pasta an intangible cultural heritage of humanity (Bresciani, et al. 2022). Despite the high consumption of pasta in the United States, there have been no effects on obesity of comsumers. In addition, once the pasta is properly cooked, it can have a low glycaemic index are free of cholesterol and low in sodium (EMR 2023).

In the last two decades, there has been much research effort into improving the nutritional value of pasta by inclusion of nonconventional ingredients. These ingredients can affect the technological properties of the pasta (barley, dietary fibre, fish ingredients, herbs, inulin, resistant starches, legumes, vegetables and protein extracts) (Sissons, 2022).

Pasta should exhibit high firmness, absence of stickiness and low cooking loss . During cooking the starch granules swell and partly solubilise, while the protein becomes insoluble and coagulate (Hager et al., 2012). Gluten significantly influences the texture of cooked pasta. Understanding the relationship between changes by processing and pasta quality is essential in "redesigning" the process when alternative raw materials are used (Bresciani, et al. 2022).

Buckwheat, amaranth, quinoa, and oat are becoming increasingly popular as ingredients in pasta due to improving the nutritional quality (Kahlon and Chiu 2015). Precooked buckwheat pasta contained natural polyphenolic antioxidants e.g. gallic, protocatechuic, gentisic, 4-OH-benzoic, vanillic, trans-caffeic, cis-caffeic, trans-pcoumaric, cis-pcoumaric, trans-ferulic, cis-ferulic and salicylic (Oniszczuk 2016), But they affect the texture, taste and odor of the pasta (Gao et al. 2018). Health efects together with good taste, texture and appearance at an acceptable price are important for the consumer demand for such foods (Sissons 2022).

2 Aim of the Thesis

The aim of this work was to test the possibility of pasta production with different proportions of buckwheat sprouts and evaluate their selected qualitative properties.

3 Material and Methods

Material

The sample of common buckwheat (Pyra variety) achenes (500g) from organic farming were cleaned and freed from foreign. Composition: fat 1.6 g, carbohydrates 46 g, fiber, 25 g, protein 11 g.

Semolina flour was purchased from Granoro Italy. Composition: fat 1.5g, carbohydrate 71 g, fibre 3g, protein 12.5 g

Sprouts and microgreens preparation

For buckwheat sprout production, 200 g of seeds surface-sterilized with UV rays was pre-soaked in sterile water for 4 h. The seeds for sprouts production were directly placed into 40×40 cm plastic trays with four sheets of filter paper (KA 1) saturated with sterile water. The germinating systems were incubated in the thermostat at 25±1°C under dark conditions. The seedlings were sprayed daily to facilitate pericarp shedding. Achenes were germinated for 96 hours for buckwheat sprouts (malt) preparation.

For microgreens the achenes were directly placed into a double-bottomed container. Hemp non-woven fabric was placed on the upper perforated bottom of the container with 1x1 cm holes, and buckwheat achenes were placed on the fabric. The container was closed with an opaque lid for 5 days. Then the lid was removed. Plants were incubated in the thermostat at 25±1°C under dark conditions all the time. Eleven days after the start of the experiments, sprouts were cut 10 mm above the surface for microgreens.
The rest of the pericarp on microgreens and sprouts was removed manually. The plant material was weighted and dried in ventilated oven at 50±1°C for 24 h. The final weight of the dried sprout powder was recorded.

Preparation of pasta

For the production of pasta, sprouts and microgreens were ground into flour. Four mixtures were produced. Mixtures of flour were prepared containing from 10, 15, 20% of buckwheat flour from sprouts or 10% of buckwheat flour from microgreens, the remainder up to 100% by weight being semolina. As a control, pasta was made only from semolina flour. This was followed by manual kneading of the dough from 100 g of a mixture with 48 ml of distilled water at 47±1° C, the kneading time was 20 minutes. Then, pasta with a width of 1 cm and a thickness of 2 mm was produced. These were then dried for 6 hours in a hot air oven with maximum 90 ° C (at 30 for 30 min and h for 50°C for pre-drying and 2 h at 90°C and then 2 hours for 60°C for drying).

Individual pasta samples (100g) were boiled about 10 minutes in 1 liter of water at 100° C, with the addition of 10 g of salt. The experiments were performed in two replicates.

Evaluated parameters

Optimal cooking time

The optimal cooking time was recorded as the time to when the white cores of the strands disappeared, according to Approved Method 66-50 of AACC International

Cooking water absorption

Binding is the determination of water content in percentage by weight which the test pasta has taken on during cooking. Immediately after cooking, the pasta was drained and left in the sieve for 2 minutes. They were then placed on a pre-weighed dish and weighed. 100 g (weight of pasta before cooking) was deducted from the net weight of pasta after cooking. The resulting value indicates the amount of water in weight percent. The cooked pasta was drained and weighed to determine water absorption.
Water absorption (WA) is expressed in m/m % and obtained by the following formula:where:

WA (%) = (a – b) /b * 100
a: weight of the cooked pasta (g),
b: weight of the dry pasta (g).

Cooking yield

Percentage of increased weight of pasta during cooking was calculated as a cooking yield.

Swelling index

Volume increase (swelling) is the ratio volume of test pasta before and after cooking, expressed as a multiple of the original volume of solution. Dry pasta (100 g) was placed in a graduated cylinder with 700 ml of water. The measuring cylinder was gently shaken to remove air bubbles between the pasta and the water level in ml was read. Subsequently, the pasta was drained through a sieve and placed in a kitchen pot with 1 liter of boiling distilled water with the addition of 10 g of salt and cooked for 10 minutes. After this time, the pasta was drained. The pasta was left to stand in the sieve for 2 minutes to allow the water to drip. Subsequently, they were placed in a graduated cylinder with 700 ml of water, and the water level in the cylinder was read. To calculate the swelling index the water displacement of cooked pasta was divided on the water displacement of an equivalent amount of uncooked pasta.

Cooking loss

Solids (g) extracted from the cooking water were determined by concentrating the cooking water to dryness in an oven at 100 °C.

Adhesion

how cooked the pasta sticks to the fork compared to the semolina pasta

Scale: 1 - does not stick to the fork at all

2 - easily sticks to the fork

3 - medium glues to the fork

4 - a lot of sticks to the fork

5 - strongly sticks to the fork

Sensory evaluation

Sensory evaluation of pasta was performed by a group of 10 people (5 women and 5 men). The evaluators were not in contact with each other and were not familiar with the composition of the pasta. Individual samples were marked with numbers only. They were evaluated first pasta in raw and then cooked state. The evaluation took place on a scale 1 to 5, with a rating of 1 corresponding to the best and a rating of 5 to the worst impression. The overall rating was determined by the arithmetic mean. For raw pasta, the color, overall appearance (shape, edges), surface properties (smooth, semi-smooth, rough), elasticity and breaking strength between fingers, translucency. The appearance of the surface is an important property of pasta, as well as the color, shape, consistency and taste. It plays an important role in consumer decision-making (Fongaro et al., 2013). After cooking, it was evaluated: color, appearance of pasta with a focus on shape and surface, aroma according to character and pleasantness, taste according to character and pleasantness and overall impression.

Sensory evaluation scale

Raw pasta:

Color

1-great 2- excellent 3- less excellent 4- good 5- unsatisfactory

Overall look

1-great 2-excellent 3- less excellent 4 good 5- unsatisfactory

Surface

1-smooth 2-less smooth 3-coarse 4- slightly rough 5- rough

Flexibility (strength puts up resistance before breaking)

1-puts up resistance before it breaks 2- puts up slight resistance before breaking 3- it breaks easily4- it breaks almost immediately 5-fragile, cannot be bent, breaks immediately

Translucency

1-like semolina 2-almost like semolina 3-only along the edges 4-almost none 5-none

Cooked pasta:

Color

1-great 2- excellent 3- less excellent 4- good 5- unsatisfactory

Overall look

1-great 2- excellent 3- less excellent 4- good 5- unsatisfactory

Flavour

1-great 2- excellent 3- less excellent 4- good 5- unsatisfactory

Taste

1-great 2- excellent 3- less excellent 4- good 5- unsatisfactory

The overall impression

1-great 2- excellent 3- less excellent 4- good 5- unsatisfactory

Statistical evaluation

The influence of buckwheat portion on selected parameters was evaluated by analysis of variance with the post hoc Tukey HSD test in program Statistica 12.0.

4 Results

Optimal cooking time

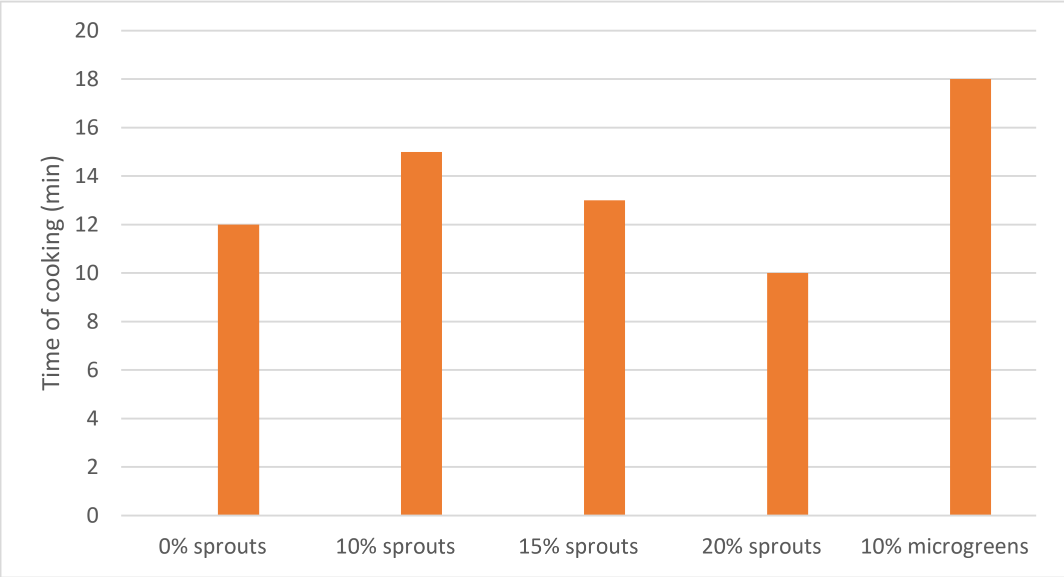


Figure 4.1: Optimal cooking time of pasta with different portion of buckwheat sprouts or microgreens (average ± standard deviation)

The cooking time of pasta with microgreens was different to the pasta with buckwheat sprouts, and it was also significantly higher (18 min) than in pasta from semolina (0% buckwheat sprouts). While significantly the lowest (10 min) cooking time was recorded in pasta with 20% of buckwheat sprouts. The increasing proportion of buckwheat sprout flour in the pasta reduced their cooking time (Figure 4.1.)

Cooking water absorption

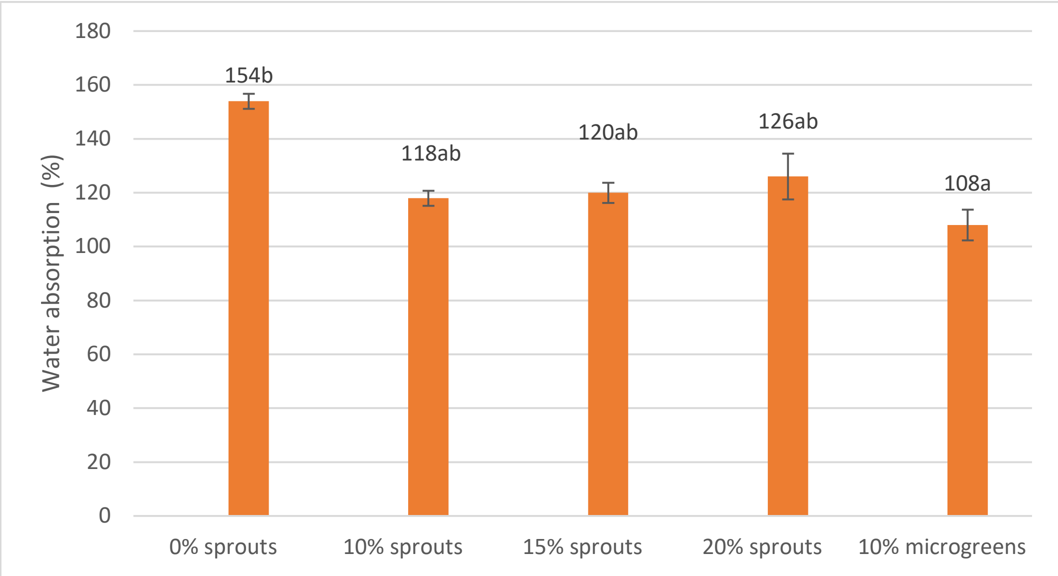


Figure 4.2: The cooking water absorption of pasta with different portion of buckwheat sprouts or microgreens (average ± standard deviation)

The cooking water absorption is the amount of water in weight percent that the pasta is taken by cooking. In case of insufficient binding, the cooked pasta is hard and rough, on the contrary, with high binding, the pasta is too soft and sticky.

The increase in weight of pasta with different portion of buckwheat sprouts or microgreens after cooking caused by water absorption was significantly different among variants. The highest cooking water absorption of pasta (154%) was observed in the control variant (0% sprouts) and the lowest cooking water absorption (108%) was recorded in pasta with buckwheat microgreens. The higher cooking water absorption increase was noticed in the pasta with sprouts than that pasta with microgreens. There was no statistically significant difference between pasta varieties with a different proportion of sprouts in the cooking water absorption (Figure 4.2.).

Cooking yield

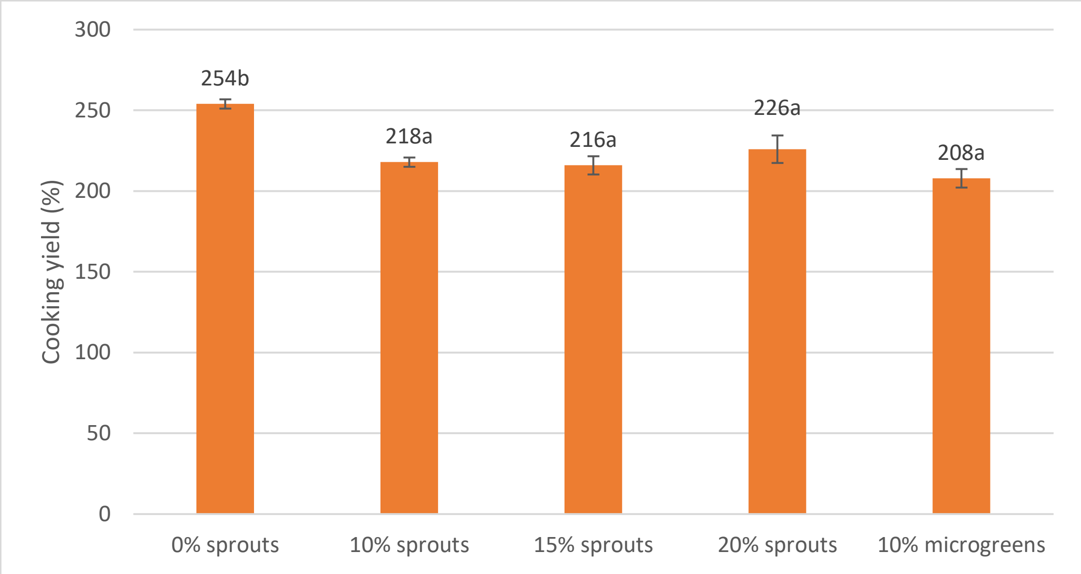


Figure 4.3: The cooking yield of pasta with different portion of buckwheat sprouts or microgreens (average ± standard deviation). Different small letters (a–b) indicate significant differences.

From the figure 4.3 it emerged that the cooking yield of pasta was statistically significantly higher for the control sample than for the other prepared pasta variants.

The highest cooking yield of pasta (245%) was observed in the control variant (0% of sprouts) and lowest cooking yield (208%) was recorded in pasta with buckwheat microgreens. The higher cooking yield was noted in the pasta with sprouts than that pasta with microgreens, There was no statisticaly significant difference between pasta variants with the different proportion of sprouts in the cooking yield.

Swelling index

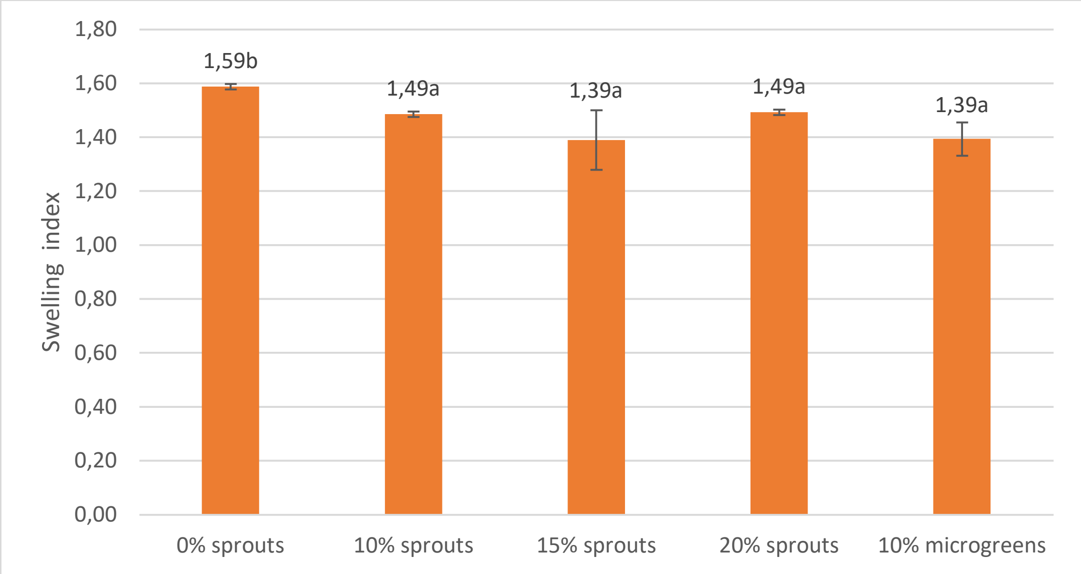


Figure 4.4: Swelling index of pasta with different portion of buckwheat sprouts or microgreens (average ± standard deviation). Different small letters (a–b) indicate significant differences.

The highest volume of pasta due to water absoption (40 ml) and also the highest swelling index (1.59) was observed in pasta with 0% portion of sprouts (the control variant). The lowest volume (32 ml) and also the lowest swelling index was recorded in pasta with 10% of microgreens. There was a statistically significant difference between these two variants. On the other hand, there were no significant difference among pasta with different portion of sprouts or microgreens in swelling index (Figure 4.4).

Cooking loss

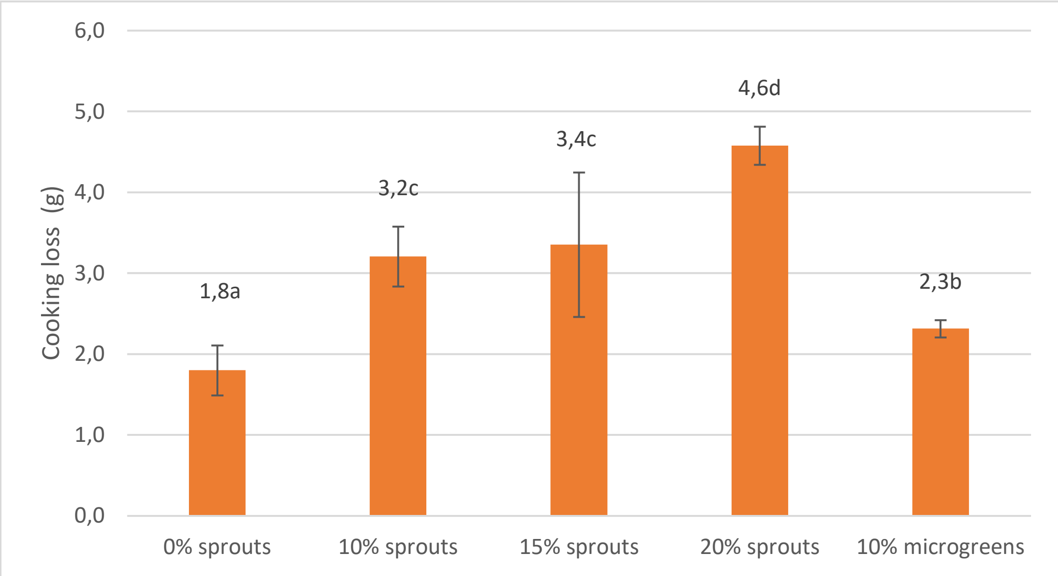


Figure 4.5: Cooking loss of pasta with different portion of buckwheat sprouts or microgreens (average ± standard deviation). Different small letters (a–b) indicate significant differences.

Cooking loss defined as a weight of the total solids lost in the cooking water. The higher portion of the solids lost is, the cooking losses are higher. Replacement of wheat flour by buckwheat sprouts and microgreens significantly ($p < 0.05$) increased the cooking loss. There was statisticaly significant difference between pasta variants with the different proportion of sprouts. The pasta prepared from flour with 10% of buckwheat microgreens had the most similar cooking loss of the control sample. The highest cooking loss values were observed when the pasta was prepared with 20% of portion of buckwheat sprouts (Figure 4.5).

Adhesion

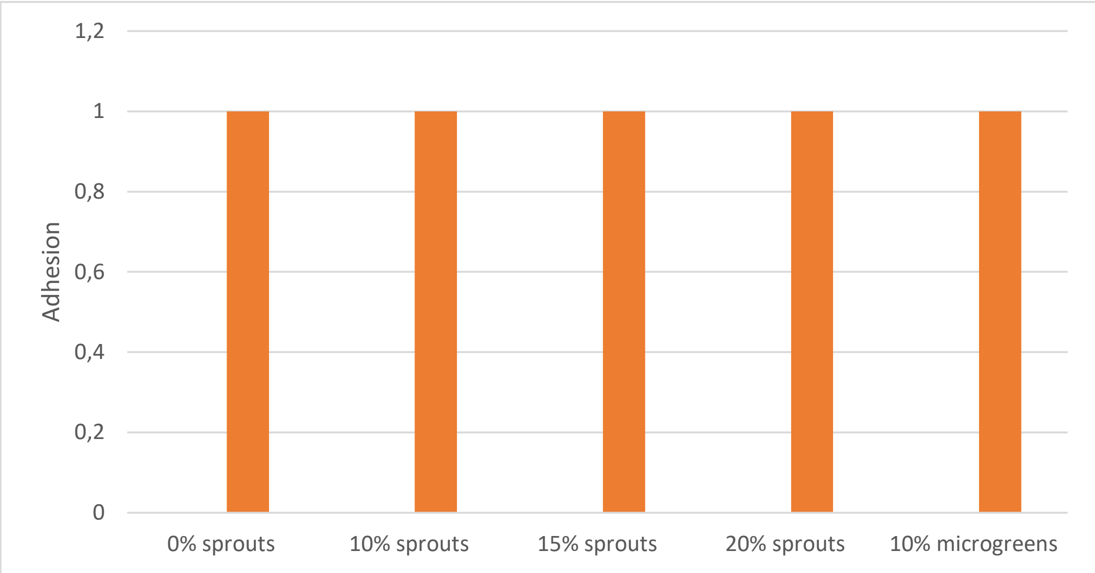


Figure 4.6: Adhesion of pasta with different portion of buckwheat sprouts or microgreens

Stickiness is another important property of pasta. If the pasta sticks, it worsens their consumption. The stickiness of the pasta was tested as adhesion to a fork. Adhesion was not significantly different among tested variants of pasta (Figure 4.6).

Sensory evaluation of pasta

Table 4.1. Sensory evaluation of raw pasta (average ± standard deviation)

	Color		Overal look		Surface properties		Flexibility		Translu-cency		Total mark
0% of sprouts	2	0.5	1	0.4	1	0.5	3	0.5	1	0.5	2
10% of sprouts	2	0.4	2	0.4	2	0.0	3	0.0	2	0.7	2
15% of sprouts	3	0.8	3	0.5	3	0.5	3	0.0	4	0.0	3
20% of sprouts	4	0.8	5	0.5	3	0.5	3	0.3	5	0.0	4
10% of microgre-ens	4	0.8	3	0.4	3	0.4	3	0.5	5	0.4	4

The sensory evaluation of raw pasta variants fortified with sprouts is presented in Table 4.1. Higher scores of sensory characteristics are recorded for color and trasluency which had pasta with 10% of microgreens and 20% of sprouts..

There was no difference among pasta variants with the different proportion of sprouts in surface properties and flexibility. The overall acceptance and total marker of cooked pasta was found the best in control pasta without buckwheat sprouts and for pasta with 10% of buckwheat sprouts.

Table 4.2. Sensory evaluation of cooked pasta (average +standard deviation)

	Color		Overal look		Flavour		Overal impresion		Total mark
0% of sprouts	1	0	1	0	2	0.7	2	1.1	2
10% of sprouts	3	0.5	2	0.5	3	0.5	3	0	3
15% of sprouts	3	0.5	3	0.8	3	0.5	3	0	3
20% of sprouts	5	0.3	5	0.5	5	0.5	4	0.5	5
10% of microgreens	4	0.7	4	0.5	3	0.7	4	0.5	4

The sensory evaluation of cooked pasta variants fortified with sprouts is presented in Table 4.2. Higher scores of sensory characteristics are related to 20% of sprouts and 10% of microgreens for color, overal look, flavour, overal impresion and also for total marker

The overall acceptance of cooked pasta was found the best in control pasta without-buckwheat sprouts. Pasta with 15% sprouts was evaluated as less excellent in all characteristics.

5 Discussion

In this study, I evaluate the characteristics of a raw and cooked pasta, which was developed in The Laboratory of Plant Production, Faculty of Agriculture and Technology, and contain buckwheat sprouts for the improvement of their nutritional quality of the human diet.

In the first step, the starting raw material was obtained - buckwheat sprouts and microgreens, which is the best both from a commercial point of view (productivity) and from a healthy aspect. In the next step, pasta with different proportions of flour obtained from buckwheat sprouts and microgreens was prepared and the following characteristics were compared: optimal cooking time, water absorption during cooking, cooking yield, swelling index, loss during cooking and adhesion.

Furthermore, the effects of processing and cooking on the sensory properties of pasta such as color, overall appearance, taste and overall impression were evaluated. It was found that the addition of buckwheat sprouts to the pasta dough negatively affected the cooking time and color of the pasta. The addition of sprouts at the level of 20% adversely affected the color and other sensory properties. However, the 10% addition of buckwheat sprouts is acceptable to consumers both in terms of appearance and taste, and at the same time it will positively affect the nutritional quality of the pasta.

These findings are in agreement with those previously reported by Bojňanská et al. (2002) in a study regarding the Use of Common Buckwheat in the Production of Baked and Pasta Products, where he states that the application of buckwheat to pasta can have an important role in human nutrition because the consumption of pasta has a long-term upward trend in the population. An important feature of pasta is its high flexibility in terms of its possible enrichment with different raw materials. Analysis and evaluation of pasta prepared with the addition of buckwheat flour to wheat flour confirmed that, from a nutritional point of view, the application of buckwheat to the dough brought a high protein and mineral content, which was also transferred to the cooked pasta. The pasta cooking time, the binding of water, which is absorbed during pasta cooking and causes it to swell, which expresses the increase in the volume of the cooked pasta, as well as the proportion of sediment or cooking losses, confirmed satisfactory values of these parameters for all experimental pasta samples. After evaluating the sensory quality of the pasta before and after cooking, it can be stated that the sensory profile of the pasta was at a comparable level to the control products. According to Bojňanská et al. (2002) all additions increased the rutin content in buckwheat-enriched pasta in proportion to the amount of addition. Based on the findings and the obtained results, common buckwheat sprouts can be recommended as an ingredient in pasta.

Conclusions

- The addition of buckwheat sprouts in the formulation of pasta had significant effects on their color value, cooking quality and overall look.
- As the supplementation percentage of buckwheat sprout increased in pasta their weight after cooking.
- The buckwheat sprouts negatively affected cooking and color evaluations of pasta.
- As a result of the sensory evaluation, the overall acceptance of pasta was found best in pasta supplemented with 0% buckwheat sprout in raw and 0% in cooked.
- Addition of 20% buckwheat sprouts may adversely affected color and sensory properties.
- Based on the obtained results, the addition of sprouts other than microgreens can be recommended for the fortification of pasta
- It can be concluded that 10% buckwheat sprout addition will improved the nutritional quality of pasta and pasta are acceptable to consumers.

References

Anonym (2021). Global microgreens market forecasts report 2020-2025. [online] (Accessed 24 Feubruary 2023) Available at: https://www.businesswire.com/news/home/20210106005435/en/Global-Microgreens-Market-Forecasts-Report-2020-2025-Focus-on-Broccoli-Cabbage-Cauliflower-Peas-Basil---ResearchAndMarkets.com

Bárta, J. et al (2004). Effects of environmental factors on protein content and composition in buckwheat flour. *Cereal Research Communications*, 32(4): 541-548.

Becker, H. et al (1994). Hirse und reis-die schäl-und spelzgetreide und ihre bedeutung für die ernährung. AID - Verbrauchrdienst, 39(6): 123-130.

Bojňanská, T. et al. (2022). Use of common buckwheat in the production of baked and pasta products. *Pseudocereals*, 11. [online] (Accessed 24 Feubruary 2023) Available from https://www.intechopen.com/chapters/80087

Bonafaccia, G., & Fabjan, N. (2003). Nutritional comparison of tartary buckwheat with common buckwheat and minor cereals. *Zb. Bioteh. Fak. Univ. Ljublj. Kmet*, *81*(2): 349-355.

Bonafaccia, G., et al. (2003). Composition and technological properties of the flour and bran from common and tartary buckwheat. *Food Chemistry*, *80*(1): 9-15.

Brentlinger D.J. (2007). New trends in hydroponic crop production in the US. *Acta Hort. (ISHS)* 742:31-33

Campbell CG (1997). Buckwheat. Fagopyrum esculentum Moench. Promoting the conservation and use of underutilized and neglected crops. 19. Institute of plant genetics and crop plant research, Gatersleben/International Plant Genetics Resources Institute, Rome, Italy

Campbell, C. (2003). Buckwheat crop improvement. *Fagopyrum*, *20*: 1-6.

Choe U. et al. (2018). The science behind microgreens as an exciting new food for the 21st Century. *J. Agric. Food Chem.*, 66:11519–11530.

Choi, M. K.,et al (2015). Physicochemical composition of buckwheat microgreens grown under different light conditions. *Journal of the Korean Society of Food Science and Nutrition*, *44*(5): 709-715.

Dwyer, J. T. et al. (2015). Fortification and health: challenges and opportunities. *Advances in Nutrition*, *6*(1): 124-131.

Ebert, A. W. (2022). Sprouts and Microgreens—Novel Food Sources for Healthy Diets. *Plants*, *11*(4): 571

Efloras.org (2022). Flora of Pakistan. [online] (Accessed 24 Feubruary 2023) Available at: http://efloras.org/object_page.aspx?object_id=44793&flora_id=5

Eggum, B. O. et al (1980). Chemical composition and protein quality of buckwheat (Fagopyrum esculentum Moench). *Plant Foods for Human Nutrition*, *30*(3): 175-179.

FAOSTAT (2022). Food and Agriculture Data. Food and Agricultural Organization of United Nation. [online] (Accessed 20, Febuary 2023) Available at: https://www.fao.org/faostat/en/#home

FDA (1999). Food and Drug Administration. Super Sprout LLC. [online] (Accessed 18 August 2020) Available at: https://col.st/LYARG

Food Source Information (2022). A food production wiki for public health professional. [online] (Accessed 18 August 2020) Available at: https://fsi.colostate.edu/sprouts/

Galieni, A. et al. (2020). Sprouts and microgreens: Trends, opportunities, and horizons for novel research. *Agronomy*, *10*(9): 1424

Gondola, I., & Papp, P. P. (2010). Origin, geographical distribution and phylogenic relationships of common buckwheat (Fagopyrum esculentum Moench.). *The European Journal of Plant Science and Biotechnology*, *4*(1): 17-32

Hosaka, T. et al. (2011). Extracts of common buckwheat bran prevent sucrose digestion. *Journal of Nutritional Science and Vitaminology*, *57*(6), 441-445.

Janovská, D. et al. (2010). Evaluation of buckwheat sprouts as microgreens. *Acta Agriculturae Slovenica*, *95*(2): 157.

Jansen P.C.M. (2006). Fagopyrum esculentum Moench. In: Brink M, Belay G.(Eds) PROTA 1: Cereals and Pulses/Céréales et Légumes Secs. PROTA, Wageningen, Netherlands.

Javornik, B., & Kreft, I. (1984). Characterization of buckwheat proteins. *Fagopyrum*, *4*, 30-38.

Kalinová, J. P. et al. (2019). Phenolics levels in different parts of common buckwheat (Fagopyrum esculentum) achenes. *Journal of Cereal Science*, *85*, 243-248.

Kim, S. L. et al. (2004). Introduction and nutritional evaluation of buckwheat sprouts as a new vegetable. *Food Research International*, *37*(4), 319-327.

Kim, S. L. et al. (2001). Development and utilization of buckwheat sprouts as functional vegetables. *Fagopyrum*, 18, 49–54

Klopsch, R. et al. (2018). Bread enriched with legume microgreens and leaves—Ontogenetic and baking-driven changes in the profile of secondary plant metabolites. *Frontiers in Chemistry*, 6*:* 322.

Kou, L. et al (2013). Postharvest biology, quality and shelf life of buckwheat microgreens. *LWT-Food Science and Technology* 51(1), 73-78.

Kreft, I. (2020). Grenko seme tatarske ajde. *SAZU: Ljubljana, Slovenia*, 79.

Kyriacou, M. C. et al. (2016). Micro-scale vegetable production and the rise of microgreens. *Trends in Food Science & Technology*, *57*, 103-115.

Luthar Z., et al. (2021). Tartary buckwheat in human nutrition. *Plants* 10 (4): 700

Ma, Y., & Xiong, Y. L. (2009). Antioxidant and bile acid binding activity of buckwheat protein in vitro digests. *Journal of Agricultural and Food Chemistry*, *57*(10), 4372-4380.

Marshall, H. G. (1982). Buckwheat: description, breeding, production, and utilization. *Adv. Cereal Sci. Technol.* 5: 157-210.

Mazza, G. (1986). Buckwheat browning and color assessment. *Cereal Chemistry*, 63(4): 361-364

MicroGreensUSA. (2009). [online] (Accessed 24 Feubruary 2022) Available at: http://www.microgreensusa.com

Michalová A. (2000). Minor Cereals and Pseudocereals in Europe. IN: Maggioni, L. Report of a Network Coordinating Group on Minor Crops. First meeting, June 16, 1999, Türku, Finland. IPGRI, Rome, Italy.

Michalová A. (2003). Buckwheat in the Czech and Slovak Republic. In: Kreft I. et al. Ethnobotany of Buckwheat, Jinsol Publishing Company, p.154,

Michalová, A. and Čejka, L. (1997). Hodnocení nutriční hodnoty u vybraných genotypů pohanky. Pohanka setá – význam ve zdravé výživě, výzkum, pěstování a tržní realizace. VÚRV, Praha, 26-35

Mordor Intelligence Platform (2020). Precise market intelligence and advisory, [online] (Accessed 24 Feubruary 2022) Available at: https://www.mordorintelligence.com/

Moreira-Rodríguez, M. et al. (2017). UVA, UVB light, and methyl jasmonate, alone or combined, redirect the biosynthesis of glucosinolates, phenolics, carotenoids, and chlorophylls in broccoli sprouts. *International Journal of Molecular Sciences*, *18*(11): 2330.

Murphy, C.J. (2010). Factors affecting the growth of microgreen table beet. *Int J Veg Sci.* 16:253–66.

Ohnishi, O. (1992). Buckwheat in Bhutan. *Fagopyrum* 12: 5-13.

Ohsako, T., & Li, C. (2020). Classification and systematics of the Fagopyrum species. *Breeding Science*, *70*(1). 93-100.

Parashivu, M. et al. (2021). Microgreens-current status, global market trends and forward statements. *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, *21*(3): 633-639.

Park, B. et al. (2004). Comparison in rutin content in seed and plant of tartary buckwheat (*Fagopyrum tataricum*). In: *Proceedings of the 9th international symposium on Buckwheat*, Prague, 626-629.

Pomeranz, Y. & Lorenz, K. (1983). Buckwheat: structure, composition, and utilization. *Critical Reviews in Food Science & Nutrition*, *19*(3): 213-258.

Sharma, S. et al. (2022). Vegetable microgreens: The gleam of next generation super foods, their genetic enhancement, health benefits and processing approaches. *Food Research International*, 111038.

Skrabanja, V. et al. (2001). Nutritional properties of starch in buckwheat products: studies in vitro and in vivo. *Journal of Agricultural and Food Chemistry*, *49*(1): 490-496.

Skrabanja, V. et al. (1998). Effects of hydrothermal processing of buckwheat (Fagopyrum esculentum Moench) groats on starch enzymatic availability in vitro and in vivo in rats. *Journal of Cereal Science*, 28(2): 209-214.

Steadman, K. J. et al. (2001). Buckwheat seed milling fractions: description, macronutrient composition and dietary fibre. *Journal of Cereal Science*, *33*(3): 271-278.

Sytar, O. et al. (2018). Nutrient capacity of amino acids from buckwheat seeds and sprouts. *Journal of Food & Nutrition Research*, *57*(1).

Treadwell, D. et al. (2020). Microgreens: A New Specialty Crop: HS1164, (5).

Wiczkowski, W. D. et al. (2016). Profile of phenolic acids and antioxidant capacity in organs of common buckwheat sprout. *Acta Alimentaria* 45 (2):250-257.

Wojdyło, A. et al. (2020). Sprouts vs. microgreens as novel functional foods: Variation of nutritional and phytochemical profiles and their in vitro bioactive properties. *Molecules* 25(20): 4648.

Xiao, Z. et al. (2012). Assessment of vitamin and carotenoid concentrations of emerging food products: edible microgreens. *J. Agric. Food Chem.* 60:7644–51.

Xiao, Z. et al. (2015). Evaluation and correlation of sensory attributes and chemical compositions of emerging fresh produce: Microgreens. *Postharvest Bio Tech*. 110:140–48.

List of Figures

Figure 0.1: *Fagopyrum esculenthum* (Efloras.org 2022)……………………………9

Figure 0.2: Production share of buckwheat by region in 2020 (FAOSTAT 2022)…..11

Figure 0.3: A variety of crops can be grown as microgreens (Treadwell et al. 2020)..16

Figure 0.4: Microgreens Market: market size, by region in 2020 (Mordor Intelligence Platform 2020)……………………………………..……………………..17

Figure 0.5: Sprout production proccess (FDA, 1999)………………………………18

Figure 0.6: Nutritional and functional importance of microgrrens according to Sharma et al., (2022)……………………………………………………………………20

Figure 0.7: Buckwheat sprouts (a) and production system(b, c) (Kim e t al. 2004)…21

Figure 0.8: Changes of vitamin B1+B6 and vitamin C contents in buckwheat sprouts according to days after seeding (9im e t al. 2004)……………………………………22

Figure 1.9: Carotenooids and alfa-tocopherol in common and tartary microgreens (ug.g-1 DM) (Janovská et al. 2010)……………………………… ……………..23

Figure 1.10: Antioxidant activity (DPPH assay) of different varieties of common buckwheat - seeds and microgreens comparison (mg galic acid equivalent . g-1 DM) (Janovská et al. 2010) …………………………………………………………..23

Figure 4.1: Optimal cooking time of pasta with different portion of buckwheat sprouts or microgreens (average ± standard deviation)………………………………………33

Figure 4.2: The cooking water absorption of pasta with different portion of buckwheat sprouts or microgreens (average ± standard deviation)……………………………..34

Figure 4.3: The cooking yield of pasta with different portion of buckwheat sprouts or microgreens (average ± standard deviation)……………………………………… 35

Figure 4.4: Swelling index of pasta with different portion of buckwheat sprouts or microgreens (average ± standard deviation)……………………………………… .36

Figure 4.5: Cooking loss of pasta with different portion of buckwheat sprouts or micro-greens (average ± standard deviation)…………………………………… ………..37

Figure 4.6: Adhesion of pasta with different portion of buckwheat sprouts or micro-greens…………………………… ……………………………………………38

List of tables

Table 1.1: Chemical composition (% dry matter basis) of tartary and common buckwheat (Bonafaccia & Fabjan 2003)……………………………………………11

Table 1.2 Essential amino acid composition of buckwheat and other cereals (% of protein) (Campbell 1997) ……………………………………………………………12

Table 1.3: Amino acid composition of proteins from the grains of common buckwheat (mean ± standard deviation on dry weight basis) (Sytar et al. 2018)………………..12

Table 1.4: Average mineral and vitamin contents of buckwheat (Marshall 1982)….14

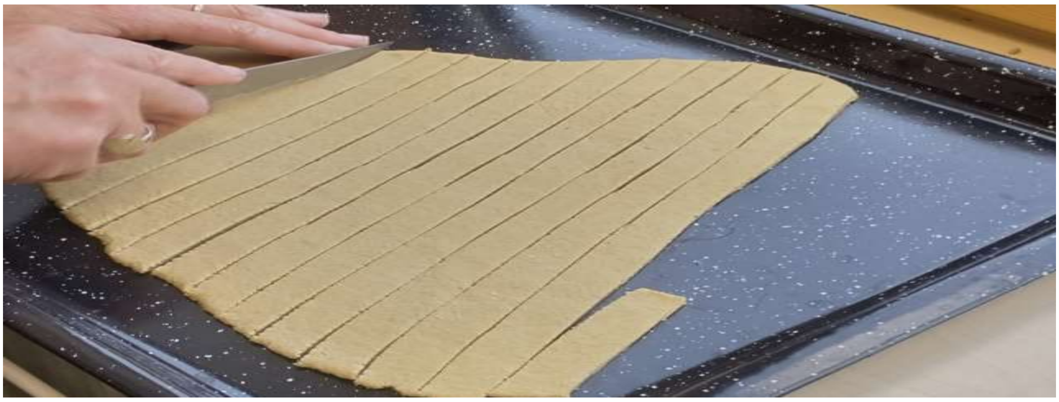
Table 1.5: The rutin content (mg /100g) in common buckwheat (Park et al., 2004)…15

Table 4.1: Sensory evaluation of raw pasta (Average + standard deviation)………..39

Table 4.2: Sensory evaluation of cooked pasta (Average +standard deviation)……..39

Image Attachment

Sprouts preparation for drying



Pasta production

Dried pasta before storing in the refrigerator

Cooked pasta before sensory evaluation