International Journal of Plant & Soil Science

Volume 36, Issue 3, Page 402-409, 2024; Article no.IJPSS.113438
ISSN: 2320-7035

Exploitation of Buckwheat (*Fagopyrum esculentum* Moench) Grains for Physical and Functional Properties

Bhagyajyothi C. Kotibagar [a++*], Uma N. Kulkarni [b#], Sarojani Karakannavar [c†], U. K. Hulihalli [d‡] and Ashwini M. [e^]

[a] Department of Food and Nutrition, College of Community Science, University of Agricultural Sciences, Dharwad, Karnataka-580005, India.
[b] Department of Food and Nutrition, Food Safety and Quality Assurance, College of Community Science, UAS, Dharwad, Karnataka-580005, India.
[c] UAS, Dharwad, Karnataka-580005, India.
[d] Department of Agricultural Meteorology, College of Agriculture, UAS, Dharwad, Karnataka-580005, India.
[e] Department of FSQA, Food Technology, College of Community Science, UAS, Dharwad, Karnataka-580005, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2024/v36i34439

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/113438

Original Research Article

Received: 06/12/2023
Accepted: 09/02/2024
Published: 21/02/2024

[++] PhD Scholar;
[#] Professor and Head;
[†] Dean (Student Welfare);
[‡] Rtd., Professor and Head;
[^] Assistant Professor;
**Corresponding author: E-mail: bhagyaj215@gmail.com;*

ABSTRACT

Buckwheat is neither a nut nor a cereal but is included in a separate group called “pseudocereals”. Buckwheat grains contain high levels of protein, starch, dietary fibre, some minerals, vitamins, flavonoids and other bioactive compounds. The main aim of the study is to analyse physical and functional properties of buckwheat grains. The results showed that bread wheat (control) had significantly higher length (5.91 mm), length to width ratio (2.06) and lower width (2.86 mm) compared to other buckwheat varieties. In the present study, higher thousand grain weight and volume were recorded for bread wheat compared to buckwheat varieties indicating bolder grains of former. Significantly higher bulk (0.70 g/ml) for and true densities (2.08 g/ml) for Dharwad Selection-1 may be regarded as a consequence of volumes and shape of grains. Buckwheat varieties showed higher greenness (-0.80 to -1.14) lower brightness (78.12 to 82.36) and yellowness (6.30 to 8.09) compared to bread wheat. Chroma being higher for bread wheat (10.06) indicates having high brightness and saturation compared to buckwheat varieties (6.40-8.13). Hydration capacity and swelling index were higher for buckwheat varieties compared to bread wheat. where, in case of hydration index and swelling capacity it was vice versa. The overall information on physical properties plays an important role in food processing and its knowledge is essential to design the equipment for handling, aeration, storing and processing of food grains.

Keywords: Buckwheat; pseudocereal; flavonoids; bioactive compounds; dietary fibre; grains.

1. INTRODUCTION

“Buckwheat is a traditional crop across Asia, Central and Eastern Europe, and the Middle East. China has been the world's greatest producer of buckwheat for the last 40 years” [1]. “Buckwheat is thought to have originated in Central Asia; nevertheless, its domestication dates back approximately 4000-5000 years in South China and is rich in buckwheat genetic resources. Buckwheat belongs to the family Polygonaceae and genus Fagopyrum. Buckwheat is mostly grown in India, Nepal, Bhutan, Canada, China, Mongolia, North Korea, far eastern Russia and Japan. In India, buckwheat is cultivated in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, West Bengal, Meghalaya, Arunachal Pradesh and Manipur” [2].

“The name buckwheat originated from the Anglo-Saxon words boc (beech) and whoet (wheat). The three-sided angular seed resembles a small beechnut” [3]. Buckwheat is grown on 2.4 million ha of land worldwide, with average yield and productivity of 2.4 million tonnes and 1000 kg/ha, respectively. Russia ranked first in both buckwheat area (1.12 Mha) and production (1.19 million tonnes) among the world's buckwheat-growing countries, followed by China and Ukraine. In terms of productivity, France has the highest buckwheat productivity in the world (3735 kg/ha) [4]. “Buckwheat, on the other hand, is neither a nut nor a cereal, but is classified as a "pseudocereal" because it has both similarities and distinctions with cereals. Among the various underutilized crops, buckwheat is one of the ancient domesticated crops of Asia, Central, and Eastern Europe that has been mainly used as a staple food especially in arid regions of the world” [5].

Seed shape and size vary depending on the type. In terms of gross chemical composition and structure, seed is made up of a thick outer hull and an inner groat that mimics the cereal kernel. Buckwheat hull has a lower density than water, making it easier to separate the hull from the kernel [2]. Buckwheat grows in a cool, damp climate and a variety of soil types. Buckwheat is a cover crop and can be utilized as a useful green manure crop since it produces an enormous amount of dry matter [3]. Buckwheat is considered as a smart crop in intercropping systems. Cultivation of buckwheat is low-maintenance and well-suited to environmentally friendly agriculture. It is extremely resistant crop that can be cultivated in an array of soil types, including infertile, rocky and poorly tilled fields [5] where no other grain crop can possible be grown [6]. It tolerates both poor and acidic soils, as well as light soils, but thrives best in well-drained sandy or silty soils. As a result of fast germination, grows fast and large above the found biomass, buckwheat is comparatively less affected from weeds and diseases are rare [7]. “Buckwheat cultivation had declined for many years, but in recent times its resurgence of interest in its cultivation due to the grain's high levels of protein, starch, dietary fibre, some

minerals, vitamins, flavonoids, and other bioactive compounds" [8].

However, limited information is available on physical and functional properties of buckwheat varieties in comparison with wheat. Physical and functional characteristics are defined as "the physical and chemical properties of proteins that influence their behaviour in food systems during processing, storage, cooking, and consumption" [9]. The objective of this study was to determine physical properties of buckwheat grains.

2. MATERIALS AND METHODS

The study was conducted in the Department of Food and Nutrition, University of Agricultural Sciences, Dharwad.

2.1 Procurement of Raw Materials

Buckwheat varieties, such as Dharwad Selection–1, PRB-1, VL–7, IC- 42412 and IC-79147 along with bread wheat (control) were procured from MARS, University of Agricultural Sciences, Dharwad during kharif 2021. Other ingredients were procured from a particular shop in the local market of Dharwad. Care was taken to purchase ingredients of same brand and quality throughout the study.

2.2 Physical Properties of Buckwheat Grains

2.2.1 Length

Length of randomly selected 10 buckwheat grains were measured by using slide caliper. Mean length was expressed in mm as given by Unal et al. [10]

2.2.2 Width

Width of randomly selected 10 buckwheat grains were measured by using slide caliper. Mean width was expressed in mm as given by Unal et al. [10]

2.2.3 Length/width ratio

Length/Width ratio was calculated by using length and width values of respective grains.

2.2.4 Hundred grain weight (g)

Three sets of 100 intact buckwheat grains were selected randomly using procedure of Williams et al. [11] with some modifications. The mean weight was expressed in g/100 grains. Weight of selected grains was recorded in triplicates using electronic weighing balance and average was calculated.

2.2.5 Hundred grains volume (ml)

The volume of buckwheat grains was measured by water displacement method using procedure of Williams et al. [11] with some modifications. Hundred randomly selected grains were dropped in measuring cylinder containing known volume of water. The rise in volume was recorded in ml. The volume of grains were calculated by subtracting the initial volume from final volume. Mean of three readings was expressed in ml as volume of hundred grains

2.2.6 Bulk density

Bulk density was calculated using hundred grain weight and volume of buckwheat grains as given by Williams et al. [11].

> Bulk density (g/ml) = Weight (g) / Volume (ml)

2.2.7 True density

25 g of grains were filled into the measuring cylinder and volume occupied by them was measured. It was then calculated by following formula and represented in g/ml as outlined by Bhavsar et al. [12].

> True density (g/ml) = Weight of grains / Volume occupied

2.3 Color

Buckwheat grains were selected randomly and were packed in transparent pouches. The samples were subjected to color assessment in Konica Minolta spectrophotometer of model CM 2600/2500d as described by Garg et al. [13]. The color was assessed for L* (lightness/ black to white), a* (redness/ redness to greenness) and b* (yellowness/ yellowness to blueness). Chroma, an expression of the purity or vividness or saturation of a single color, was calculated by using the formula= $(a^{*2}+b^{*2})^{0.5}$. Hue value measures most obvious value of a color, and was calculated by using the formula= $\tan^{-1}(b^*/a^*)^2$

2.4 Functional Properties of Buckwheat Grains

Functional properties like hydration capacity, hydration index, swelling capacity and swelling index were assessed for buckwheat varieties.

2.4.1 Hydration capacity (g/100 grains)

About 10 g of seeds were counted and transferred to a measuring cylinder. The 50 ml of water was added to cylinder and covered with aluminum foil and left 24 hours at room temperature (27ºC). The seeds were drained, superfluous water was removed with filter paper and swollen seeds were reweighed. Hydration capacity and hydration index was calculated using the following formula given by Sangeetha and Grewal [14].

> Hydration capacity (g/100 grains) = [Weight of grains after soaking (g) - Weight of grains before soaking (g)] / Total number of grains (N)

2.4.2 Hydration index

Hydration index was calculated by using formula:

> Hydration index = Hydration capacity / Weight of seeds

2.4.3 Swelling capacity and swelling index

Seeds weighing 10 g were counted and transferred to a measuring cylinder and Total volume was recorded. For soaking, 50 ml of water was added. The cylinder was covered with aluminium foil and 24 hours at room temperature (27ºC). The water was drained and volume of soaked seeds was noted in graduated cylinder. Swelling capacity and swelling index was calculated using the following formulae as given by Sangeetha and Grewal [14].

> Swelling capacity = [Volume of seeds after soaking (ml) - Volume of seeds before soaking (ml)] / Total number of seeds (N)

2.4.4 Swelling index

Swelling index was calculated by using the formula,

> Swelling index = Swelling capacity per 100 seed / Volume of 100 seeds

2.5 Statistical Analysis

The data were subjected to analysis of variance (ANOVA) by Statistical Package for Social Science software (SPSS Version 23.0) at a 5% level of significance. Ducan's multiple range test (DMRT) was used to compare least square means.

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Buckwheat Grains

The results pertaining to physical properties of buckwheat varieties are depicted in Table 1. The length and length/width ratio of buckwheat varieties, Dharwad Selection-1, PRB-1, VL-7, IC-42412, IC-79147 were 3.99 mm and 1.22, 3.95 mm 1.24, 4.35 mm and 1.42, 4.28 mm and 1.36, and 4.01 mm and 1.22 respectively which were significantly lower compared to bread wheat (5.91 mm and 2.06). Whereas, width of bread wheat (2.86 mm) was significantly lower compared to buckwheat varieties, Dharwad Selection-1 (3.27 mm), PRB-1 (3.17 mm), VL-7 (3.07 mm), IC-42412 (3.14 mm) and IC-79147 (3.28 mm). Hundred grain weight (g) and hundred grain volume (ml) were 2.20 and 3.10, 1.85 and 2.73, 1.96 and 2.86, 1.91 and 2.82, 1.94 and 2.88, 4.08 and 7.03 respectively for Dharwad Selection-1, PRB-1, VL-7, IC-42412, IC-79147 and bread wheat respectively. Being significantly higher ($p \leq 0.05$) for bread wheat compared to other buckwheat varieties. Seed weight represents the grain size and big grain size means easy for processing. Big size grain has got more endosperm therefore has more edible portion. The results were in accordance with length and width of buckwheat reported by Unal et al. [10]. “Seed weight, seed volume and seed density related information are important for easy post-harvest processing of the food grains. These parameters are most often used and the oldest quality indices” [15]. In the present study, higher thousand grain weight and volume were recorded for bread wheat compared to buckwheat varieties (Table 1) indicating bolder grains of former. Significant difference among the varieties may be influenced by influenced by many factors, including fungal infection, insect damage, kernel shape and density, broken and shrivelled kernels, agronomic practice, climatic and the weather conditions [15].

Theories used to forecast pressure and loads on storage structures necessitate understanding of bulk density and true density against bin wall materials. Data on bulk density and true density (Table 1) are also required for the design of grain hoppers for processing machines. However, bulk density and true density were found to be significantly higher in Dharwad Selection-1 (0.70 & 2.08 g/ml respectively). PRB-1, IC-42412 and IC-79147 possessed same value for bulk density (0.67 g/ml), VL-7 had 0.68 g/ml. Next to Dharwad

Table 1. Physical properties of buckwheat varieties

Varieties	Length (mm)	Width (mm)	Length/ Width ratio	100 grain weight (g)	100 grain volume (ml)	Bulk density (g/ml)	True density (g/ml)
Bread wheat (Control)	5.91±0.16^{a}	2.86±0.13^{b}	2.06±0.12^{a}	4.08±0.05^{a}	7.03±0.05^{a}	0.58±0.02^{c}	1.34±0.01^{b}
Dharwad Selection-1	3.99±0.07^{c}	3.27±0.08^{a}	1.22±0.03^{c}	2.20±0.04^{b}	3.10±0.11^{b}	0.70±0.04^{a}	2.08±0.18^{a}
PRB-1	3.95±0.20^{c}	3.17±0.14^{a}	1.24±0.04^{c}	1.85±0.05^{c}	2.73±0.05^{c}	0.67±0.04^{bc}	1.01±0.47^{c}
VL-7	4.35±0.28^{c}	3.07±0.20^{a}	1.42±0.09^{c}	1.96±0.05^{bc}	2.86±0.01^{bc}	0.68±0.02^{bc}	1.07±0.03^{c}
IC-42412	4.28±0.81^{b}	3.14±0.18^{ab}	1.36±0.09^{bc}	1.91±0.28^{bc}	2.82±0.28^{bc}	0.67±0.03^{bc}	1.32±0.01^{b}
IC- 79147	4.01±0.17^{b}	3.28±0.15^{ab}	1.22±0.08^{c}	1.94±0.05^{bc}	2.88±0.05^{bc}	0.67±0.03^{bc}	1.43±0.01^{b}
F value	18.95	32.24	53.11	3.04	44.11	22.17	92.37
S.Em±	2.02	1.77	0.10	0.08	0.04	0.05	0.08
CD	6.37*	5.58*	0.31*	0.27*	0.14*	0.17*	0.27*

*Note: Values are expressed as Mean ± Standard deviation of three replications, S.Em- Standard error of mean, CD – Critical difference, *- significant at @ 5%. Values with the same superscripts (a, b, c) in the same column are not significantly different.*

Selection-1, true density was found significantly high in IC-79147 (1.43 g/ml) followed by bread wheat (1.34 g/ml), IC-42412 (1.32 g/ml), VL-7 (1.07 g/ml) and PRB-1 (1.01 g/ml). This may be regarded as a consequence of volumes and shape of grains [9]. The results were in line with values reported by Baljeet [16], Sindhu and Khatkar [17], Sangeeta and Grewel [14]. Rani and Kulkarni [4] for bulk density.

3.1.1 Color values of buckwheat grains

L*, a* and b* color values were significantly higher (p≤0.05) for bread wheat (90.89, 2.11 & 9.48 respectively) followed by Dharwad Selection-1 (82.36, -0.80 & 8.09) and PRB-1 (82.26, -0.83 & 7.86 respectively). VL-7, IC-42412 and IC-79147, were on par with each other in terms of L* (78.12, 78.58 & 78.83 respectively), a* (-0.90, -1.10 & -1.14 respectively), b* (6.34, 6.30 & 6.31 respectively) and chroma (6.40, 6.42 & 6.41 respectively) values. Hue value for bread wheat (77.89), Dharwad Selection-1 (84.14), PRB-1 (83.97), VL-7 (81.92), IC-42412 (80.09) and IC-79147 (79.75) did not differ significantly. Buckwheat varieties showed higher greenness (-0.80 to -1.14) lower brightness (78.12 to 82.36) and yellowness (6.30 to 8.09) compared to bread wheat (Table 2). Chroma being higher for bread wheat (10.06) indicates having high brightness and saturation [4] compared to buckwheat varieties (6.40-8.13). The differences in the color of grain is reflected by its chemical composition, hardness [18] and pigments in the seed coat [19]. The results were in accordance with results obtained for buckwheat grits [20].

Table 2. Color values of buckwheat varieties

Varieties	Colour				
	L*	a*	b*	Hue	Chroma
Bread wheat (Control)	90.89±5.27^{a}	2.11±0.13^{a}	9.84±0.59^{a}	77.89±1.56	10.06±0.60^{a}
Dharwad Selection-1	82.36±1.75^{b}	-0.83±1.00^{b}	8.09±0.49^{b}	84.14±5.05	8.13±0.31^{b}
PRB-1	82.26±5.24^{b}	-0.80±1.60^{a}	7.86±0.24^{b}	83.97±5.88	7.90±0.21^{b}
VL-7	78.12±6.03^{c}	-0.90±0.50^{d}	6.34±0.32^{c}	81.92±3.28	6.40±0.30^{c}
IC-42412	78.58±3.46^{c}	-1.10±0.13^{d}	6.30±0.44^{c}	80.09±4.00	6.42±0.41^{c}
IC- 79147	78.83±4.34^{c}	-1.14±0.06^{cd}	6.31±0.38^{c}	79.75±4.78	6.41±0.30^{c}
F value	77.01	30.19	0.05	0.99	0.06
S.Em±	0.07	0.06	2.64	2.49	2.73
CD	0.23*	0.21*	0.13*	NS	0.24*

Table 3. Functional properties of buckwheat varieties

Varieties	Hydration capacity (g/100 grains)	Hydration index	Swelling capacity (ml/100 grains)	Swelling index
Bread wheat (Control)	3.10±0.10^{c}	1.71±0.07^{a}	5.30±0.57^{a}	1.74±0.15^{ab}
Dharwad Selection-1	3.50±0.71^{b}	1.55±0.02^{b}	2.32±0.57^{bc}	1.90±0.54^{a}
PRB-1	3.02±0.04^{c}	1.60±0.08^{b}	2.31±0.56^{bc}	1.25±0.27^{c}
VL-7	3.98±0.10^{a}	1.48±0.01^{c}	1.98±0.01^{c}	1.10±0.01^{bc}
IC-42412	3.15±0.03^{c}	1.69±0.05^{a}	2.98±0.02^{b}	2.08±0.37^{a}
IC- 79147	3.05±0.0^{6c}	1.61±0.02^{b}	2.65±0.57^{bc}	1.93±0.34^{a}
F value	718.76	13.59	19.89	4.40
S.Em±	0.04	0.02	0.27	0.19
CD	0.13*	0.08*	0.83*	0.55*

*Note: Values are expressed as Mean ± Standard deviation of three replications, S.Em- Standard error of mean, CD – Critical difference, *- significant at @ 5%. Values with the same superscripts (a, b, c) in the same column are not significantly different.*

3.2 Functional Properties of Buckwheat Grains

Table 3 summarized the functional properties of buckwheat grains. Hydration capacity was ascertained to be higher for VL-7 (3.98 g/100 grains) followed by Dharwad Selection-1 (3.50 g/100 grains), IC-42412 (3.15 g/100 grains), bread wheat (3.10 g/100 grains), IC-79147 (3.05 g/100 grains) and PRB-1 (3.02 g/100 grains). Conversely hydration index was significantly lower for VL-7 (1.48) followed by Dharwad Selection-1 (1.55), PRB-1 (1.60), IC-79147 (1.61), IC-42412 (1.69) and bread wheat (1.71). Respective values for hydration capacity and swelling index obtained by Kumari and Raghuvanshi [21] and Rani and Kulkarni [4] on buckwheat were lower compared with present study results. Swelling capacity was 2.32 ml/100 grains for Dharwad Selection-1, 2.31 ml/100 grains for PRB-1, 1.98 ml/100 grains for VL-7, 2.98 ml/100 grains for IC-42414, 2.65 ml/100 grains for IC-79147 and 5.30 ml/100 grains for bread wheat, being significantly higher compared to other buckwheat varieties. Significantly higher swelling index was noted in IC-42412 (2.08) variety in comparison with Dharwad Selection-1 (1.90), PRB-1 (1.25), VL-7 (1.10), IC-79147 (1.93) and bread wheat (1.74). Hydration index (1.71) and swelling capacity (5.30 ml/100 grains) known to be higher in bread wheat in comparison to buckwheat varieties (1.48-1.69 and 1.98-2.98 ml/100 grains respectively). This may be correlated to higher seed weight of the bread wheat compared to buckwheat varieties. Srivastava *et al.* [22] also reported positive correlation between seed weight and swelling capacity in chickpea. And also, these variations may be attributed to difference in carbohydrate and proteins. The particle size of flour is important role in defining the texture of foods. Finer particles contribute to smoother textures, but coarser particles can provide granular or gritty textures [23-25].

4. CONCLUSION

There were significant differences observed in various physical and functional properties buckwheat grains. the variations in the physical and functional properties may be influenced largely due to the inherent properties, like chemical composition and nutritional quality of the grains and also due to dufferent agronomic practice, climatic and the weather conditions. However, the physical and functional properties of buckwheat grains were comparable with bread wheat. The buckwheat can be blended with other grains for the preparation of different kind of food products because its grains have good physical and functional properties.

ACKNOWLEDGEMENT

I would like to acknowledge RKVY Project, University of Agricultural Sciences, Dharwad. Karnataka, India and Karnataka Science and Technology Promotion Society (KSTePS), Department of Science and Technology, Government of Karnataka for financial assistance throughout the course of this research project. Their funding played a crucial role in enabling me to conduct this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Wijngaard HH, Arendt EK. Buckwheat. Cereal Chemistry. 2006; 83(4): 391-401.
2. Tahir I, Farooq S. Review article on buckwheat. Buckwheat Newsletter, Fagopyrum. 1988;8:33-53.
3. Berglund, Duane R, Buckwheat production. NDSU Extension Service Publication. 2003;687.
4. Rani RL, Kulkarni UN. Physical and functional properties of buckwheat. Journal homepage. 2020;9(4):1-6.
5. Farooq S, Rehman RU, Pirzadah TB, Malik B, Dar FA, Tahir I. Cultivation, agronomic practices, and growth performance of buckwheat. In Molecular Breeding and Nutritional Aspects of Buckwheat, Academic Press. 2016;299-319.
6. Taylor RW. Buckwheat: Cooperative Extension, University of Delaware, College of Agriculture and Natural Resources; 1998.
7. Jacquemart AL, Cawoy V, Kinet JM, Ledent JF, Quinet M. Is buckwheat (Fagopyrum esculentum Moench) still a valuable crop today. The European Journal of Plant Science and Biotechnology. 2012; 6(2):1-10.
8. Qin P, Wu L, Yao Y, Ren G. Changes in phytochemical compositions, antioxidant and α-glucosidase inhibitory activities during the processing of tartary buckwheat tea. Food Research International. 2013;50 (2):562-567.

9. Kinsella JE, Melachouris N. Functional properties of proteins in foods: A survey. Critical Reviews in Food Science and Nutrition. 1976;7(3):219-280.
10. Unal H, Izli G, Izli N, Asik BB. Comparison of some physical and chemical characteristics of buckwheat (Fagopyrum esculentum Moench) grains. CyTA-Journal of Food. 2017;15(2):257-265.
11. Williams PC, Nakoul H, Singh KB. Relationship between cooking time and some physical characteristics in chickpeas (*Cicer arietinum* L.). Journal of the Science of Food and Agriculture. 1983;34(5):492-496.
12. Bhavsar GJ, Sawate AR, Kshirsagar RB, Chappalwar VM. Studies on physico-chemical characteristics of buckwheat and its exploration in bread as functional food. International Journal Engineering Research Technology. 2013;2(1):3971-3980.
13. Garg M, Chawla M, Chunduri V, Kumar R, Sharma S, Sharma NK, Singh SP. Transfer of grain colors to elite wheat cultivars and their characterization. Journal of Cereal Science. 2016;71: 138-144.
14. Sangeeta, Grewal RB. Physico-chemical properties of pseudo-cereals (*Amaranth and buckwheat*). The Pharma Innovation Journal. 2018;7(3):07-10.
15. Dziki D, Laskowski J. Wheat kernel physical properties and milling process. Acta Agrophysica. 2005;6(1):59-71.
16. Baljeet SY, Ritika BY, Roshan LY. Studies on functional properties and incorporation of buckwheat flour for biscuit making. International Food Research Journal. 2010;17(4):1067-1076.
17. Sindhu R, Khatkar BS. Morphological, pasting and thermal properties of common buckwheat (Fagopyrum esculentum Moench) flour and starch. International Journal of Innovative Research and Advanced Studies. 2016;3(7):160-164.
18. Tańska M, Buczek J, Jarecki W, Wasilewska A. Konopka I. Grain morphology, texture and colour-related compounds of bread wheat cultivars in relation to cultivation regimes and growing location. Zemdirbyste-Agriculture. 2018; 105(2).
19. Boz H, Gercekaslan KE, Karaoğlu MM, Kotancilar HG. Differences in some physical and chemical properties of wheat grains from different parts within the spike. Turkish Journal of Agriculture and Forestry. 2012;36(3):309-316.
20. Kasar C, Thanushree MP, Gupta S, Inamdar AA. Milled fractions of common buckwheat (*Fagopyrum esculentum*) from the Himalayan regions: Grain characteristics, functional properties and nutrient composition. Journal of Food Science and Technology. 2021;58:3871-3881.
21. Kumari N, Raghuvanshi RS. Physico-chemical and functional properties of buckwheat (Fagopyrum esculentum Moench). Journal of Eco-friendly Agriculture. 2015;10(1):77-81.
22. Srivastava AK, Dixit GP, Nisar M, Singh NP, Genetic variability and inter-relationships among grain physical and hydration traits in chickpea. Legume Research-An International Journal. 2023; 46(5):664-667.
23. Khanh TD, Chung MI, Xuan TD, Tawata S. The exploitation of crop allelopathy in sustainable agricultural production. Journal of Agronomy and Crop Science. 2005; 191:172-184.
24. Bilgicli N. Effect of buckwheat flour on cooking quality and some chemical, antinutritional and sensory properties of eriste, Turkish noodle. International Journal of Food Sciences and Nutrition. 2009;60(4):70-80.
25. FAOSTAT, Production-yield quantities of buckwheat in world? (total). 1961–2016; 2018.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/113438