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Physicochemical and Functional Properties of Starch and Flour of Tartary Buckwheat (F. Tataricum) Grains.

Ritu Sindhu[1] and Bhupendar Singh Khatkar[1]
Department of Food Technology,
GJUS&T, Hisar -125001 (Haryana), India

Abstract - **The present work was carried out to evaluate the physicochemical (Composition, hunter color, and paste clarity) and functional properties (water and oil absorption capacities, swelling power and solubility, least gelation concenteration and bulk density) of flour and starch fraction of tartary buckwheat grains. Process of isolation of starch removed all other components such as protein, fibre and fat which resulted in production of good quality of starch isolate with high proportion of starch and low level of other components except amylose. Chemical composition of flour showed better nutritional value of buckwheat flour than strch. Color of starch was having slight yellowness but higher luminosity increase scope of its utilization as a food ingredient. Paste clarity and gelation capacity of starch was higher than flour indicating it a better thickening agent. Swelling power of starch was higher than flour indicating its suitability for application in processed foods. Solubility, oil absorption and water absorption capacities of flour and starch representing their technologically important properties meeting the demand of consumer preference in food industry.**

Keywords- Starch; Functional; Flour; Buckwheat.

1. INTRODUCTION

Buckwheat is confusing to many as it seems to express relationship to wheat which is not true. The name is may be a modification of "beech-wheat" (German Buckweizen) from the resemblance of its - grains with beechnuts, (Singh and Atal, 1982). Buckwheat is an annual dicotyledonous crop, which belongs to Polygonaceae family. The main producers of buckwheat are China, Russian Federation, Ukraine, and Kazakhstan (Li & Zhang, 2001; Bonafaccia et al., 2003). It is also produced in some other countries such as Slovenia, Poland, Hungary, and Brazil (Kreft et al., 1999). For many years, the cultivation of buckwheat had declined, but recently there has been a resurgence of interest in its cultivation because the grain of buckwheat is highly nutritious due to high levels of protein, starch, dietary fibre, some minerals, vitamins, flavonoids and other bioactive compounds (Krkoskova and Mrazova, 2005). In general, two main buckwheat species are grown and consumed around the world: common buckwheat (*Fagopyrum esculentum Moench*) and tartary buckwheat (*F. tataricum*) (Li and Zhang, 2001; Bonafaccia et al., 2003). In India, tartary buckwheat is grown in mountainous regions where the climate is cold, dry, and harsh, has a higher resistance to stress than common buckwheat. Tartary buckwheat is acknowledged for its high level of bioactive nutrients and components like dietary fibre, protein and antioxidants and multiple health benefits (Li et al., 1997). Major storage component of buckwheat grain is starch ranging from 59% – 69% which is 15-25% is amylose and rest is apmylopectine. Buckwheat starch granules are spherical, oval and polygonal in shape with noticeable flat areas due to compact packing in the endosperm (Christa and Soral-Śmietana, 2008). Soral-Smietana et al., (1984) studied a Polish and a Brazilian buckwheat sample and found a perhaps questionably high amylose content of approximately 50% in both samples. Fornal et al., (1987) found very high swelling power of buckwheat starch relative to barley and maize. Buckwheat is generally utilized as food in the form of flour; and starch being the major component of flour dominates the functional properties of food, especially composite flours products, containing buckwheat. Physico-chemical and functional properties of starch play an important role in understanding their cooking and processing properties. Relatively little work has been done on buckwheat starch. The present investigation was undertaken to analyse the physicochemical and functional properties of starch and flour of buckwheat.

2. MATERIALS AND METHODS

2.1. Materials

Grains of Tartary Buckwheat of cultivar named Shimla B-1 were used in this study and procured from National Bureau of Plant Genetic Resources Regional Station, Shimla, India. The grains were screened to remove defective grains and foreign matter if present and stored in sealed container at room temperature previous to their use. The flour were prepared by grinding seeds on laboratory mill and stored in polyethylene bags at 10ºC. Chemicals used for the analysis purpose were of analytical grade.

2.2. Starch isolation

Isolation of starch from grain buckwheat was done according to the alkaline steeping method (Choi et al., 2000) and stored in polythethylene bags at room temperature till further analysis. Firstly, grains were steeped in 0.25% aqueous NaOH solution for 18 h at room temperature and stirred 3-4 times during this period. After steeping, the grains were washed with distilled water and ground in a blender at full speed for 3 min, and slurry was filtered step wise through 100 mesh (150µm), and 270 mesh (53µm) sieves. The filterate was centrifuged at 25,000g for 20 min. The supernatant was discarded, and the top yellowish layer of protein was removed. This step was repeated to obtain a white starch layer. The starch layer was resuspended in distilled water, shaken and centrifuged as described above. Thereafter, the isolated starch was dried in hot air oven at below 40ºC and stored at room temperature in sealed container.

2.3. Chemical composition

Samples of starch and flour were estimated for their moisture, crude fat, crude fibre ash and protein (N x 6.25) content by employing the standard methods (A. O. A. C., 1990). The amylose content was determined following the modified method of Williams et al., (1970). The standard curve used for amylose was Y = 0.0089X + 0.0528 (r= 0.99), where X = amylose content (%), and Y = absorbance at 680 nm, based on fractionation of rice starch by Montgomery and Senti (1958). All chemical components were calculated on dry basis except moisture content.

2.4. Hunter color parameters

Color of the flour and starch was measured using Ultra Scan VIS Hunter Lab (Hunter Associated Laboratory Inc., Raston Va., U. S. A.). The system determines the L^*, a^* and b^* values , where L^* represents lightness and darkness; a^* represents the opposition between green and red color ranging from positive (red) to negative (green) values; and b^* is the yellow/blue opposition also ranging from positive (yellow) to negative (blue) values.

2.5. Functional properties

2.5.1. Water and oil absorption capacity

Method of Ige et al. (1984) was used for determination of water absorption capacity (WAC) and oil absorption capacity (OAC) of flour and starch. A suspension of 1.5g of sample in 10ml distilled water was agitated 4 times allowing 10 minutes resting periods between each mixing and centrifuged at 3250 rpm for 25 minutes. The supernatant was decanted and tubes were air dried and then weighed. For determination of OAC, 3ml refined groundnut oil was added to 0.5g of sample and stirred for 1 minute. After 30 minutes at room temperature the tubes were centrifuged at 3200 rpm for 25 minutes. The volume of unabsorbed oil was determined.

2.5.2. Swelling power and solubility

Method of Raina et al. (2006) was used for determination of swelling power and solubility of flour and starch. Flour and starch samples (4g) were heated with 40 ml of water at 90°C for 1 hour. Lump formation was prevented by stirring. The dispersion was centrifuged at 4,500 rpm for 10 min. Starch sediment was weighed and supernatant was carefully taken in pre-weighed petri dish and dried to constant weight in drying oven at 100°C. The residue obtained after drying of supernatant represented the amount of starch/flour solubilized in water. Swelling power was calculated by using following formula-

$$\textbf{Swelling Power} = \frac{\textbf{Wt of sediment paste x 100}}{\textbf{Wt of sample on dry basis x}\ (\mathbf{100} - \ \%\ \textbf{solubility})}$$

2.5.3. Paste clarity

Light transmittance (%) of pastes from starch and flour was measured by following the method of Perera and Hoover (1999) with slight modifications. Aqueous suspension (1%) of starch and flour was heated in water bath at 90ºC for 1 hour with constant stirring to avoid lump formation. The suspension was cooled to room temperature. Samples were stored for days at 4°C, and transmittance was measured at an interval of 24 hour at 640 nm against a water blank using GENESYS 10S UV–VIS Spectrophotometer (Thermo Fisher Scientific, 81 Wyman Street Waltham, MA USA).

2.5.4.Bulk density and Least gelation concenteration

Bulk density of flour and starch were determined by as per the method as described by Balandran Quintana et al. (1998). Sample (10g) was put in measuring cylinder, tapped 10-12 times from a particular height and volume of sample was recorded. Bulk density was measured as weight of sample per unit volume. The method described by Mishra and Rai (2006) was followed with slight modifications to determine the least gelation concentration. Solutions (5ml) of different concentrations of starch (1-10% w/v) and flour (8-30% w/v) in test tubes were heated at 90°C in a water bath for 1 hour, cooled immediately in ice chilled water bath and kept overnight at 4°C. The gelation was confirmed by inverting the test tubes.

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3. RESULT AND DISCUSSION

TABLE 1. Chemical composition of flour and starch of tartary buckwheat

	Moisture content (%)	Protein (%)	Crude fat (%)	Crude fibre (%)	Ash content (%)	Amylose content (%)
Flour	9.92±0.54	13.91±0.74	2.42±0.91	4.06±0.23	2.81±0.04	14.99±0.29
Starch	5.39±0.22	0.91±0.20	0.7±0.02	0.5±0.0	0.33±0.11	32.12±0.24

Values expressed as mean ± SD (n=3).

The proximate composition of tartary buckwheat flour and starch is presented in Table 1. The values of crude protein, crude fat and ash content of flour were 13.91%, 2.42% and 2.81% respectively and found to be in range reported by Pandey et al. (2015) while fibre content (4.06%) of flour was found to be higher than recorded by Bhavsar et al. (2013). Bonafaccia et al. (2003) reported 6.29% total fibre and 10.3% protein in tartary buckwheat flour. Moisture content of flour was in range reported to maintain the storage life of flour of mostly cereals. Slight difference in composition of flour from previous record might be due to difference in climatic conditions of crops. Results of starch analysis for protein, fat and ash were in consistent with the observation of earlier studies (Mundigler, 1998; choi et al., 2004). There was huge difference in the composition of flour and starch due to decreased level of protein, fat, fibre and ash content in starch. Protein and fibrous materials were removed during starch isolation for purity of product, ash content reduced due to removal of lots of minerals during washing of starch pallet; only starch bound fat could not be removed during isolation process. Additionally the presence of polar lipids interacted with proteins cannot be ruled out (Kikugawa et al., 1981). A smaller amount of moisture content was noticed in starch, which might be due to longer period of drying after extraction, and that was in ranges generally accepted for dry products in order to obtain desirable shelf life and other conventional starches (Sriroth et al., 2000). Amylose content is an important factor affecting functional properties like swelling power and solubility of flour and starch. The fraction of amylose in tartary buckwheat flour was 14.99% which was lower than the range (19-28%) reported by Qin et al. (2010) for thirty nine varieties of buckwheat flour. Amylose content of starch (32.99%) was in range with the corresponding results of 22% to 33% amylose content of buckwhwat starch reported in studies (Li et al., 1997; Pandey et al., 2015) , and comparable to the amylose content of cereal, root, tuber and legume starches. However, amylose content of buckwheat was also reported as high as 46.6% (Qian et al., 1998). The chemical composition is a simple and convenient way of illustrating the purity of the starch extracts whereby lower contents of other components (protein, fat, ash, fiber) are highly desirable and which could be noticed in present study.

TABLE 2. Hunter color properties of starch and flour of tartary buckwheat

	Color parameters		
	L^*	a^*	b^*
Flour	80.27±0.18	1.36± 0.02	16.87±1.17
Starch	98.13±0.19	0.66±0.0	7.59±0.25

Values expressed as mean ± SD (n=3).

Most important characteristics that can decide successful applications of functional ingredients in different food products are color and clarity. The colour of starch due to the presence of polyphenolic compounds, ascorbic acid and carotene has impact on its quality. Any pigmentation in the starch is carried over to the final product. This reduces the quality, hence acceptability of starch product (Galvez and Resurreccion, 1993). The L^* value of flour (80.27) was found to higher than the range (65-75) reported by Qin et al. (2010) for buckwheat flour. However L^* value of starch (99.13) was higher than that noticed for flour which indicated higher luminosity of starch. Values of a^* of flour and starch were positive indicating presence of slight red tint. However Li et al. (1997) observed negative values of a^* for some varieties of tartary buckwheat. Positive b^* value indicated presence of yellow components in starch and flour. The higher b* value has been reported to be an indication of presence of higher ash content (Kaur & Singh, 2007) and the present study agreed with it showing higher b^* value for flour (16.87) than starch (7.59) which might be due to higher ash content of flour than starch. Compared to starches from other sources, tartary buckwheat starch was more yellow and yellowness of tartary buckwheat starch cannot be avoided by the distilled water starch isolation procedure (Li et al., 1997). Thus in the present investigation tartary buckwheat starch was visually a light yellow powder compared to the white powder starch of cereals.

TABLE 3. Effect of storage on paste clarity of starch and flour of tartary buckwheat

	Transmittance (%)					
	Storage period (days)					
	0	1	2	3	4	5
Flour	7.81±0.1	4.53±0.08	40.07±0.03	3.87±06	3.74±0.04	3.11±0.01
Starch	13.60±0.05	11.07±0.03	10.50±0.1	9.53±0.11	9.11±0.12	8.99±0.05

Values expressed as mean ± SD (n=3).

The transmittance values of paste of starch and flour of buckwheat stored at refrigeration temperature are summarized in Table 2. Transmittance was found to decrease with progressive storage at refrigeration temperature in both the samples. In flour samples transmittance values decreased from 7.81 to 3.11 and in starch samples it decreased from 13.60 to 8.99 during storage of 5 days period. Transmittance value of starch was more than flour indicating comparatively higher clarity of starch paste than flour paste. The swelling of granules, granule remnants, leached amylose and amylopectine, molecular weight and chain lengths of amylose and amylopectine have been reported to vary with granule size, which ultimately leads to turbidity development and decreased transmittance in starch paste during refrigerated storage (Perera and Hoover, 1999). Decrease in transmittance with refrigeration storage was noticed in paste of corn starch by Sandhu and Singh (2007) and in potato flour paste by Singh et al. (2005). Amylose content affects the transmittance value of paste (Lim and Seib, 1993) which could be responsible for difference in turbidity of flour and starch of buckwheat in present study.

TABLE 4. Functional properties of flour and starch of tartary buckwheat

	SP(g/g)	S (%)	WAC (%)	OAC (%)	LGC (%)	BD (g/ml)
Flour	6.54± 0.10	15.52±0.34	119±1.0	126.66±9.29	26.71±1.19	0.68±0.0
Starch	17.24±1.63	10.63±0.25	91.10±0.84	92.48±12.19	18.16±0.07	0.65±0.02

Values expressed as mean ± SD (n=3). SP = Swelling power, S = Solubility, WAC = Water absorption capacity, OAC = Oil absorption capacity, LGC = Least Gelation concentration, BD = Bulk Density.

The functional properties of buckwheat starch and flour are represented in Table 4. The water absorption capacity (WAC) is the ability of the flour to hold water against gravity wherein proteins and carbohydrates enhance the WAC of flour by providing hydrophilic parts like polar and charged side chains (Pomeranz, 1985). Values of water absorption capacity were higher than oil absorption capacity in both the samples namely starch and flour. Similar trend was noticed by Shimelis et al. (2006) for bean flour and starch. Water absorption capacity of buckwheat flour was 119% which was lower than that reported by Bhvsar et al. (2013) for buckwheat flour and wheat flour. The lower water absorption capacity of buckwheat flour could be attributed to the presence of lower level of hydrophilic constituents in it. Water absorption capacity of starch was 91.10% which was lower than study of Lui et al. (2014) observed 110% water absorption capacity of buckwheat starch. OAC of flour is due to interactions between the nonpolar amino acid side chains and hydrocarbon chains of lipid determine mouthfeel and flavour retention of products. In this study the value of OAC of flour was 126.66% that was lower than the values reported by Bhavsar et al. (2013) for buckwheat (186%) and wheat flour (167%). Oil absorption capasity of buckwheat starch was 92.48% which was found to be comparable with the results of Lui et al. (2014) noticed 110% oil absorption capacity of buckwheat starch.

Swelling power and solubility represents the extent of interaction between starch chains, within the amorphous and crystalline domains of the starch granule (Ratnayake et al., 2002). Furthermore, it is influenced by amylose and amylopectin characteristics (Chan et al., 2009). Swelling Power of starch was 17.24g/g which was found to be in consistent with the study of Lui et al. (2014) noticed 13.02g/g swelling power of buckwheat starch. Swelling power of flour was 6.54g/g which was found to be comparable with the results of Pandey et al. (2015) observed 8.38g/g swelling power of buckwheat flour. The low swelling power of buckwheat flour suggests the presence of stronger bonding forces within the interiors of starch granules and more amylose lipid complex (Tester and Morrison, 1990). Solubility of flour (15.52%) was found in agreement with results of Pandey et al. (2015) observed 12.75% for buckwheat flour. Compared with starch, the swelling power and solubility of flour was higher which might be due presence of high amount of protein and fat in flour that could form inclusion complexes with amylose. Solubility of starch was 10% which lower than flour solubility. Lui et al. (2014) recorded 20.50% solubility for buckwheat starch. Ong et al. (1995) inferred that long chains of amylopectin interact with amylose to form double helix structures that lowers the swelling and leaching of materials on cooking. This could be responsible for low solubility and swelling power of buckwheat flour and starch. The LGC concentration is the index of gelation properties which depends on the amount of starch and pasting properties of starch. LGC was found to be 26.71% and 18.16% for flour and starch respectively. Starch showed the better gelling capacity than flour which could be attributed to presence of low level of protein and lipids. The value of bulk density of flour and starch was 0.68g/ml and 0.65% respectively. Bhavsar et al. (2013) reported higher bulk density 0.86 g/ml and 0.74 g/ml for buckwheat flour and refined wheat flour. Bulk density of starch was higher than flour in this study which indicates that starch would serve as better thickeners in food products.

4. CONCLUSION

The physicochemical properties and functional characteristics of starch and flour from buckwheat propose that these may have broad possibilities as an ingredient in food systems and other industrial application. Lower level of protein, crude fibre and ash content in starch confirmed the purity of starch. Chemical composition of flour is better than starch from nutritional point of view, however from technological point of view; functional properties of starch are better and enhance the chances for preference of starch for utilization in food process industry. Superior swelling power was noticed for starch than flour which makes it potentially useful in products subjected to high temperatures. High clarity of starch paste suggests that it gives shine and opacity to the product. Least gelation concentration of flour was higher than starch, which suggests that higher amylose content and lower protein, fat and fibre content in starch increase the gelling capacity of starch granules. High luminosity observed in starch is a most desirable property in food industry.

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