Effect of soaking and germination on physicochemical and functional attributes of horsegram flour

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Abstract Horsegram is an underutilized pulse, traditionally used for treating various disorders like kidney stones, diabetes and joint pain. The present study was undertaken to optimize the soaking and germination conditions, to decrease the anti-nutritional factors and at the same time maintaining the nutritional properties of horsegram. Horsegram seeds were soaked for 6, 12 and 18 h followed by germination for 0, 24 and 48 h under different illumination conditions i.e., light and dark respectively. The soaked and germinated samples were dried in laboratory drier at 55 °C until constant moisture was achieved and was further analyzed for various quality attributes. Almost all the physicochemical and functional characteristics were significantly affected by both soaking and germination, whereas, germination done in light and dark conditions, exerted significant effect on the ascorbic acid content, total protein, total phenols, antioxidant activity and tannin content only. Based on the quality attributes, it was found that treatment having 18 h soaking and 48 h germination in the presence of light was the best where maximum decrease in the anti-nutritional factors was observed. Moreover, there was an increase in ascorbic acid, total protein content and a decrease in the anti-nutritional factors such as oxalate and tannin content. Thus, it is concluded that 18 h soaking and 48 h germination in the presence of light can be considered as the optimum conditions to increase the nutritional content of horsegram flour, which can further be utilized for the preparation of different value-added food products.

Keywords Soaking · Germination · Germination conditions · FT-IR

Introduction

Horsegram [*Macrotyloma uniflorum* (Lam.) Verdc.], earlier known as *Dolichos biflorus* (Sreerama et al. 2012) is also known as kulth, kulthi-kalai, horsegram (English) and kulattha (Sanskrit). Being a cheap source of proteins for human consumption and its use in the production of livestock, it is considered as a poor man's food (Kadam et al. 1985; Pal et al. 2016) and can be consumed in the form of whole meal, dhal or splits and sprouts. All over the world, it is extensively cultivated in dry and rain-fed land zones of Australia, Burma, India, Sri Lanka (Kadam et al. 1985), and Africa. It is a minor, underutilized legume of tropical and subtropical region, grown mostly under semi-arid rain-fed agricultural land in India. It is majorly cultivated in Maharashtra, Sikkim, Andhra Pradesh, Tamil Nadu, Karnataka and Himachal Pradesh (Prasad and Singh 2015). It is a good source of protein, carbohydrate, iron, molybdenum and calcium (Kadam et al. 1985; Pal et al. 2016). The traditional use of horsegram includes its role in treating jaundice, hyperglycemia, oedema, rheumatism, piles, abdominal lumps, hemorrhagia, cough and bronchitis (Kadam et al. 1985) and urinary stones. Moreover, it is preferred during winters to maintain the body temperature (Prasad and Singh 2015).

In addition, horsegram is also rich in certain anti-nutritional factors such as oxalic acid and phytic acid, which have the tendency to bind with calcium and iron to form an insoluble salt and hence decrease their bioavailability (Parmar et al. 2017). Hull of horsegram contains maximum amount of tannin, which can be decreased successfully by

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dehulling (Pal et al. 2016). Whereas, soaking and germination (widely used as traditional technology) are the simplest, effective and the most common methods to enhance the nutritional quality and to reduce the anti-nutritional factors of this legume. Soaking is a domestic technological treatment of hydration of seeds in water for few hours to allow the seeds to absorb water (Embaby 2010). Thus, it decreases and eliminates the anti-nutritional factors present in the legumes (Kajihansa et al. 2014; Singh et al. 2016). Soaking is done prior to a number of treatments including germination, cooking and fermentation (Khattak et al. 2008). Several studies have reported that 12–18 h soaking time is the most effective to reduce the levels of phytic acid and proteolytic enzyme inhibitors in legumes which are partly or totally solubilized in soaked water (Embaby 2010; Kajihansa et al. 2014). Soaking is followed by sprouting or germination, where the soaked seeds are left in moist conditions until they germinate in order to improve their nutritional value (Vidal-Valverde et al. 2002). It increases the concentration of bio-active compounds (Vidal-Valverde et al. 2002; Pal et al. 2016), improves the sensory characteristics (Kuo and Taylor 2004) and reduces the anti-nutritive compounds at the same time. Different researchers have reported that 24–48 h germination can successfully result in the enhancement of nutritional properties and decreasing the anti-nutritional factors of legume, whereas, too long duration may adversely affect the composition of germinated seeds (i.e., loss of nutrients and moisture) (Urbano et al. 2005). Physical conditions during germination, such as the presence of light or dark situation plays an important role in the nutritional composition of legumes (Kuo and Taylor 2004), as the presence of light during germination increases the metabolic changes (Urbano et al. 2005) thereby increasing the nutritional value of legumes.

A lot of work has been already documented regarding the effect of soaking and germination on the nutritional and anti-nutritional factors of horsegram flour but the effect of light on germination is still undocumented which needs to be explored. Moreover, a very little information is available regarding the separate effect of light on soaking and germination as well as on the nutritional and anti-nutritional factors of horsegram flour. So, the present study was aimed to fulfil these research gaps.

Materials and methods

Raw material

Horsegram seeds were purchased from the local market of Jalandhar (Punjab) which were cleaned to remove impurities and foreign materials. The seeds were washed and

soaked in tap water in glass containers (100 g seeds were soaked in 500 ml of water) at 27 ± 3 °C for 6, 12 and 18 h respectively. At the end, after draining off the soaking water, samples were allowed to germinate in humid conditions (in the presence of light and in the absence of light) for 0, 24 and 48 h respectively at room temperature (27 ± 3 °C) and then dried in a tray drier (Labfit, India) in trays (37.7×15.4) with the feed rate of 150 g/m^2 at 55 °C for 5–6 h till the achievement of constant moisture content. Raw seeds without any soaking and germination treatment served as a control. All the samples i.e., raw (control), soaked and germinated were milled to obtain flour by using super mill grinder and sieved through a 52 mesh sieve. After grinding and sieving, the respective samples were stored in airtight containers for further physicochemical, functional and FT-IR analysis. In order to study the effect of multiple replicate soaking and germination on the quality characteristics of horsegram flour, each treatment was carried out in triplicates at the same conditions.

Physicochemical analysis

TSS and titratable acidity (as citric acid) were estimated by following the AOAC method (AOAC 2005). The moisture content of different samples (control, soaked and germinated) was determined by drying to gain constant weight in an oven at 105 ± 2 °C. Ascorbic acid content was determined as per AOAC (2005) method using 2,6-dichlorophenol indophenols dye. The nitrogen content was estimated by Kjeldhal method (AOAC 2005). Total protein content was calculated as nitrogen X 6.25. Starch and total sugar were determined calorimetrically by the anthrone reagent and phenol sulphuric method respectively (Sadasivam and Manickam 1991). The total phenols content was determined by Folin Ciocalteu procedure given by Singleton and Rossi (1965) and was expressed as Gallic acid equivalents in mg per g dry weight (mg GAE/g DW). Antioxidant activity (percent radical scavenging activity) was measured as per the method of Brand-Williams et al. (1995) and was expressed as percent inhibition. Tannin content was determined calorimetrically by following the standard procedure as described by Sadasivam and Manickam (1991) and was also expressed as tannic acid equivalents in mg per g dry weight (mg TAE/g DW). Oxalic acid (OA) was determined titrimetrically by being precipitated as calcium oxalate and titrated against standard potassium permanganate (AOAC 2005).

FT-IR analysis

For the qualitative analysis, different flour samples i.e. control, best samples from soaking (18 h soaking), all the sprouted samples (dark and light) were subjected to FT-IR

analysis (Shimadzu 8400S FT-IR spectrometer, equipped with KBr beam splitter) using approximately 5 mg of each sample along with 5 mg KBr. FT-IR spectrophotometer was operated at a spectral range of 4000–400 cm^{-1} with a maximum resolution of -0.85 cm^{-1} . The spectra were interpreted using the guidelines of Stuart (2004).

Determination of functional properties

Water absorption capacity (WAC) and oil absorption capacity (OAC) were determined according to the method described by Anderson and Cronshaw (1970), Sosulski (1962) respectively. Solubility index of the flours was estimated using the standard procedure as reported by AACC (2005). Swelling capacity and swelling index of each flour sample were determined as per the method outlined by Williams et al. (1983). Foaming capacity (FC) was determined according to the procedure described by Nath and Rao (1981). Bulk density (BD) of the different samples of horsegram flour was estimated as per the procedure described by Wang and Kinsella (1976).

Statistical analysis

The data obtained from the physicochemical and functional properties of the horsegram flour were subjected to analysis of variance (ANOVA) using completely randomized design (CRD) and the means with critical differences have been reported. To get the effect of different variables (soaking and germination conditions) on horsegram flour independently, the results were expressed as means of respective measure, irrespective of the other variables.

Results and discussion

Effect of soaking time on physicochemical characteristics

With an increase in soaking time, an increase in moisture, titratable acidity, ascorbic acid and total protein content was observed, whereas, a decrease in TSS, starch, total sugars, total phenols, antioxidant activity, tannins and oxalate content was observed as compared to control (Fig. 1a). The results in Table 1 shows the effect of soaking on physicochemical characteristics of the flour prepared from soaked horsegram. With increase in soaking time, there was a significant decrease in TSS from 19.33°B (0 h) to 18.0°B (18 h soaking) which is partly or totally solubilised in the soaking water and is discarded with the soaking water. The moisture content of horsegram flour ranged from 10.01 to 12.17% which indicates that the powder was almost dry. The variation in the moisture

content for different soaking time might be due to the breakdown of cell wall of legumes thereby absorbing water rapidly. Titratable acidity was highest in flour prepared from 18 h soaked horsegram (1.20%) and was lowest in 0 h i.e. control (0.67%) owing to the enhanced ascorbic acid content during soaking in legumes, that might be due to reactivation of enzyme (L-Galactono- γ -lactone dehydrogenase) involved in the oxidation of L-galactono- 1, 4-lactone to ascorbic acid (Pérez-Balibrea et al. 2008).

While soaking, biological breakdown of various complex compounds into simpler compounds takes place as suggested by Narsih et al. (2012) and thus a significant increase in total protein content was observed with enhancement of the soaking time from 22.60 g/100 g to 28.77 g/100 g. Starch content of horsegram flour decreased significantly with soaking i.e., 46.10 g/100 g (0 h) to 31.85 g/100 g (18 h) as during soaking, leaching of other nutrients takes place leading to modification in structural components of the legume and thereby increasing the availability of starch, as reported by Marconi et al. (2000). Another reason for the reduction in carbohydrate content can be due to the use of carbohydrate as a source of energy for embryonic growth (Vidal-Valverde et al. 2002). Similar findings were reported by Modgil et al. (2012) in cow peas and Modgil et al. (2016) in fenugreek. With increase in soaking time, a gradual decrease in the total sugars from 16.04 mg/100 g to 12.18 mg/100 g was observed that might be due to the simple diffusion of sugars from the seed to the soaked water after getting solubilised in it (Silva and Braga 1982).

Phenolic content of control was 248.2 mg GAE/100 g which decreased to 170.12 mg GAE/100 g after soaking and similar results were observed in antioxidant activity (89.55–85.18%). This might be due to the leaching of water-soluble phenols into water when soaking time was increased and thus also responsible for the decrease in antioxidant activity. Tannin content of horsegram flour showed a decrease from 316.0 g/100 g to 204.1 g/100 g with an increase in the soaking time. The decline in tannin content is mainly due to the fact that these compounds, in addition to their predominance in seed coats (Reddy and Pierson 1994), are water soluble (Kumar et al. 1979) and subsequently leach into the liquid medium. The oxalate content of raw horsegram was 466 mg/100 g which decreased to 308 mg/100 g during 18 h soaking, which might be due to leaching of oxalate compound in water as previously investigated by Murugkar et al. (2013) and Pal et al. (2016).

Effect of soaking time on the functional characteristics

The results presented in Table 1 revealed an increase in water absorption, oil absorption, solubility index, swelling

Fig. 1 **a** Effect of soaking on physicochemical attributes of horsegram flour as compared to control (raw seeds). **b** Effect of germination on physicochemical attributes of horsegram flour as compared to control (0 h germination)

power and foaming capacity, whereas, a decrease in bulk density was observed with increase of soaking period. The increase in water absorption capacity of horsegram flour might be due to change in total protein structure and also due to the loosened structure of starch polymers with an increase in soaking time (Kajihausa et al. 2014). On the other hand, the reason may be that an increase in the concentration of total protein which have both hydrophilic and hydrophobic nature and therefore can interact with both water and oil in foods, and ultimately responsible for enhancement in water absorption, oil absorption capacity, solubility index (Chandra et al. 2015). Swelling power of the horsegram flour increased with an increase in soaking time (Table 1). Moorthy and Ramanujam (1986) reported that the increase in swelling power of flour samples due to the soaking treatments is an indication of the extent of associative forces within the granule and is related to the water absorption capacity. Foam capacity of protein refers to the amount of interfacial area that can be created by the protein (Chandra et al. 2015). With increase in soaking

time, an increase in the total protein is observed (Table 1) and is thus responsible for the enhancement in foaming capacity. Also with increase in soaking time, there was reduction in the bulk density which might have negative correlation with the moisture content (data not shown). Similar results have been reported by Chandra et al. (2015) in composite flours.

Effect of germination time on the physicochemical characteristics

With an increase in germination time, an increase in TSS, moisture, titrateable acidity, ascorbic acid and total sugars was observed, whereas, a decrease in total protein, starch, total phenols, antioxidant activity, tannins and oxalate was observed (Table 2; Fig. 1b).

With increase in germination time, an increase in total sugars was also observed (Martin-Cabrejas et al. 2008), whereas, the starch content was found to be decreased. This might be due to the metabolic changes that occur in legume

Table 1 Effect of soaking time on physicochemical and functional properties of raw horsegram flour

Parameters	0 h	6 h	12 h	18 h	CD ($P \leq 0.05$)
<i>Physicochemical properties</i>					
TSS (°B)	19.33	18.79	18.17	18.00	0.21
Moisture (%)	10.01	10.27	11.50	12.17	0.69
Titrateable acidity (%)	0.67	0.82	1.06	1.20	0.08
Ascorbic acid (mg/100 g)	4.00	5.33	8.00	8.67	0.52
Total protein (g/100 g)	22.60	24.73	27.52	28.77	1.48
Starch (g/100 g)	46.10	35.90	34.19	31.85	1.18
Total sugars (g/100 g)	16.04	15.58	14.40	12.18	1.06
Total phenols (mg GAE/100 g)	248.2	229.8	207.7	170.1	1.23
Antioxidant activity (% inhibition)	89.55	87.94	87.11	85.18	1.20
Tannin (mg/100 g)	316.00	292.58	263.20	204.14	33.26
Oxalate (mg/100 g)	466.00	384.67	341.00	308.00	44
<i>Functional properties</i>					
Water absorption (%)	139.54	296.45	300.78	317.56	16.23
Oil absorption (%)	78.63	299.00	287.33	302.33	14.11
Solubility index (%)	164	202.00	206.00	208.33	21.85
Swelling power (ml)	15.15	16.21	16.48	17.93	0.83
Foaming capacity (%)	35.00	35.00	38.33	45.79	3.74
Bulk density (g/ml)	0.92	0.89	0.87	0.86	0.04

Table 2 Effect of germination time on the physicochemical and functional properties of raw horsegram flour

Parameters	0 h	24 h	48 h	CD ($P \leq 0.05$)
<i>Physicochemical properties</i>				
TSS (°B)	18.67	20.83	21.67	1.42
Moisture (%)	11.80	11.80	12.33	NS
Titrateable acidity (%)	0.64	0.79	0.96	0.23
Ascorbic acid (mg/100 g)	8.67	9.33	10.00	0.52
Total protein (g/100 g)	33.44	28.79	26.79	1.48
Starch (g/100 g)	29.42	22.63	19.89	1.18
Total sugars (g/100 g)	12.42	13.82	15.92	1.06
Total phenols (mg GAE/100 g)	134.7	107.7	65.2	12.3
Antioxidant activity (% inhibition)	86.57	84.75	79.91	1.20
Tannin (mg/100 g)	199.85	159.78	100.30	33.26
Oxalate (mg/100 g)	302.00	191.00	190.67	21.63
<i>Functional properties</i>				
Water absorption (%)	318.89	340.00	345.89	16.23
Oil absorption (%)	302	289	274.67	NS
Solubility index (%)	200.00	210.00	216.33	8.19
Swelling power (ml)	16.71	16.75	17.16	NS
Foaming capacity (%)	38.00	39.67	40.67	NS
Bulk density (g/ml)	0.88	0.87	0.87	NS

seeds involving the hydrolysis of stored complex carbohydrates to the simple ones and thus decreasing starch levels from 29.42 g/100 g to 19.89 g/100 g and increasing the total sugar level from 12.42 g/100 g to 15.92 g/100 g (Table 2). It is further reported that during germination, α -galactosidase activity is increased, which causes the breakdown of α -1,6-galactosidic linkages thus, increasing

the amount of total sugar (Urbano et al. 2005; Martin-Cabrejas et al. 2008). Effect of germination on the moisture content was non-significant. As compared to the 0 h germination, a significant increase in titrateable acidity was observed which might be due to secretion of enzymes during the process of germination and therefore, resulting in the hydrolysis of complex organic molecules such as

Table 3 Effect of germination condition on the physicochemical and functional properties of raw horsegram flour

Parameters	Dark	Light	CD ($P \leq 0.05$)
<i>Physicochemical properties</i>			
TSS (°B)	21.78	21.67	NS
Moisture (%)	11.89	10.93	NS
Titrateable Acidity (%)	0.91	0.98	NS
Ascorbic acid (mg/100 g)	8.67	10.00	0.42
Total protein (g/100 g)	31.33	26.02	1.21
Starch (g/100 g)	19.41	21.21	NS
Total sugars (g/100 g)	13.99	14.12	NS
Total phenols (mg GAE/100 g)	95.2	109.8	10.0
Antioxidant activity (% inhibition)	82.93	84.55	0.98
Tannin (mg/100 g)	165.35	141.27	7.32
Oxalate (mg/100 g)	259.11	230.00	NS
<i>Functional properties</i>			
Water absorption (%)	306.59	303.25	NS
Oil absorption (%)	295.79	296.68	NS
Solubility index (%)	196.89	205.67	NS
Swelling power (ml)	16.72	17.03	NS
Foaming capacity (%)	37.78	34.44	NS
Bulk density (g/ml)	0.87	0.88	NS

phytin and protein into simpler and more acidic compounds such as phosphate and amino acids, respectively. Thus, it is responsible for the increase in titrateable acidity and decrease in pH (Adedeji et al. 2014). Results of the present study were found to be in contradiction with the findings of Ghumman et al. (2016) who reported an increase in protein content with enhancement in germination period in horsegram and lentil. Ascorbic acid content ranged from 8.67 mg/100 g to 10 mg/100 g. The increase in ascorbic acid owes to the reactivation of enzyme (L-Galactono- γ -lactone dehydrogenase) involved in the oxidation of L-galactono- 1, 4-lactone to ascorbic acid. Thus, increase in the activity of this enzyme with germination confirmed its involvement in the biosynthesis of ascorbic acid during germination (Smirnoff 2000). Similar findings have been reported in soybean by Pérez-Balibrea et al. (2008).

With increase in the germination time, the level of the protease activity get increased (Pal et al. 2016) and is thus responsible for the decrease in total protein content of the germinated mass. Similar results were observed in the present study (Table 2). With enhancement of the germination process, a significant decrease in total phenols content (134.71 mg GAE/100 g to 65.19 mg GAE/100 g) and tannin content (199.85 g/100 g to 100.30 g/100 g) was observed, which might be due to the increased activity of polyphenoloxidase and other catabolic enzymes which are activated during germination resulting in the hydrolysis of various components, including carbohydrate, protein, fiber and lipid, as well as phenolic compounds (Singh et al.

2013). A similar trend was also observed for antioxidants which is due to the positive correlation of phenolics and antioxidant activity (Gat and Ananthanarayan 2015).

A significant decrease in oxalate content was observed in the initial hours of germination i.e. 24 h followed by a non-significant change in the later stages. Decrease in oxalate during germination is because of the activation of oxalate oxidase which breakdown oxalic acid into carbon dioxide and hydrogen peroxide consequently releasing calcium and same has been previously investigated by Murugkar et al. (2013) and Pal et al. (2016).

Effect of germination time on the functional characteristics

Among all the functional properties under study, water absorption capacity and solubility index of the horsegram flour were significantly affected with the enhancement of the germination process, whereas the effect on oil absorption capacity, swelling power, foaming capacity and bulk density was non-significant (Table 2). The increase in water absorption capacity and solubility index can be attributed to the breakdown of polysaccharides into monosaccharides during germination; hence, the active sites for interaction between water and molecules increases and thus responsible for increase in these two functional properties (Table 2). Same has been reported by Sreerama et al. (2012) and Pal et al. (2016).

Fig. 2 FT-IR graph for different samples **a–f** showing peaks at different bands

Effect of germination conditions on the physicochemical characteristics

Germination conditions (germination in the presence of light and dark conditions) significantly affected the

ascorbic acid content, total protein content, phenols, antioxidant activity and tannin content of the horsegram flour (Table 3). Higher amount of ascorbic acid was found in flour prepared from seed germinated in the presence of light (10 mg/100 g) and possible reason behind it may be

Fig. 2 continued

Fig. 2 continued

the synthesis of secondary metabolites and photo protection. Thus, depicting that light during germination has significant effect on ascorbic acid (Pérez-Balibrea et al. 2008). Total protein content of the flour was influenced significantly by germination conditions, which might be due to reduced or eliminated antinutrients that affect protein utilization (Mubarak 2005). Higher amount of phenolics were detected in flour prepared from seeds germinated in the presence of light which might be due to the triggering effect of photosynthesis and malonyl-coA pathway which is related to synthesis of phenolic compounds in sprouts (Pérez-Balibrea et al. 2008). Similar trend was also observed regarding the antioxidant activity. Higher amount of tannins were observed when germination was done in dark (165.35 mg/100 g) as compared to when germination was done in the presence of light (141.27 mg/100 g) which might be due to degradation of tannic acid in the latter. However, results of the present study were in contradiction with the findings of the Urbano et al. (2005) who reported that sprouting in light or dark conditions did not influenced the nutritional value.

Effect of germination condition on the functional characteristics

Effect of germination conditions does not exert a significant effect on the functional properties of horsegram flour.

FT-IR analysis

Fourier-transform infrared spectrometry is certainly one of the most important analytical techniques available today to virtually study the physicochemical and conformational properties of any sample of different state that may be liquids, solutions, pastes, powders, films, fiber, and gas (Stuart 2004). FT-IR determines the presence or absence of a particular functional group (Stuart 2004). A comparison of Infrared spectra of different flour samples determined the structural similarities and differences between these samples. Figure 2a shows the FT-IR spectra of raw horsegram flour (control). The spectrum shows absorbance at 856, 1049, 1155, 1242, 1396, 1454, 1545, 1647, 2928, and 3365 cm^{-1} . The absorption band appearing at 856 cm^{-1} is attributed to the stretching of methyl β -D-glucopyranoside and β -D-sucrose (Stuart 2004). The peak at 1049 cm^{-1} denoting the presence of C–O stretching indicates the presence of cellulose. The peak ranging between 1600 and 1100 cm^{-1} attributes to the presence of amide groups i.e., amide I and amide II showing the presence of different amino acid such as lysine, valine, phenylalanine and tyrosin (Stuart 2004). The absorption band at 1647 cm^{-1} attributes to C=O stretching of oxalic acid (Jung et al. 2005). Peaks for C–H bonds of fat and

carbohydrate were observed in horse gram flour at the region of 2928 cm^{-1} and peak ranging between 3200 and 3600 cm^{-1} (3365 cm^{-1}) is attributed to O–H stretching of moisture content (Stuart 2004). Similar spectrum was also observed in other samples under study i.e., 18 h soaking (Fig. 2b), 18 h soaking followed by 24 h germination (in both conditions i.e. light and dark) (Fig. 2c, d) and 18 h soaking followed by 48 h germination (in both conditions i.e., light and dark) (Fig. 2e, f). A few new bands were also observed in the sprouted samples as compared to the control and soaked ones. This new absorption band ranged between 1400 and 1600 cm^{-1} which shows the presence of ascorbic acid (Xiong et al. 2011) as during sprouting there is reactivation of enzyme (L-Galactono- γ -lactone dehydrogenase) which is involved in the oxidation of L-galactono- 1, 4-lactone to ascorbic acid thus responsible for the biosynthesis of ascorbic acid and ultimately its increase in the sprouted seeds (Pérez-Balibrea et al. 2008).

Conclusion

A glimpse of the study apparently showed that soaking and germination at different conditions for different time significantly improved the physicochemical and functional properties of horsegram flour. No doubt, the antioxidant activity and total phenols were significantly decreased after soaking and germination but a significant decrease in the anti-nutritional factors i.e. tannins and oxalates was also found which helps in improving the quality of the horsegram flour and its further utilization in different food industries (baking industry) for its value addition. The developed conditions i.e. 18 h soaking and 48 h germination in the presence of light can be easily maintained by the farmers and tribal people for its value addition in cottage-scale industries and will definitely help in uplifting the economic status of those people.

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