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RESEARCH ARTICLE

EFFECT OF GERMINATION ON NUTRITIONAL QUALITY OF SORGHUM

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ABSTRACT

Sorghum grains were germinated under controlled condition and their soaking and germination time was finalized for best results. The ungerminated and germinated flours were evaluated for its chemical (proximate) and physicochemical properties. It was found that the germination of sorghum grains reduced the carbohydrate 70.02 to 60.04 (%) starch from 65.2 to 58.1 (%), amylopectin from 53.7 to 42.1 (%), ash content 1.79 to 1.39 (%), fat from 6 to 4 (%), falling number from 365 to 70 (%) and oil absorption capacity from 3.78 to 3.17 (%). The germination of grain increased the moisture content from 9.9 to 10.2 (%), total sugar from 8.92 to 11.98 (%), reducing sugar 2.81 to 3.82 (%), non-reducing sugar from 6.11 to 8.16 (%) protein content from 7.25 to 9.85 (%), amylose content from 11.5 to 15.8 (%), water absorption capacity from 121.6 to 129.6 (%), particle size from 0.029 to 0.031(μm) and water solubility index from 14 to 17 (%), respectively.

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INTRODUCTION

Germination of cereals has been used for centuries to soften kernel structure, to increase nutrient content and availability; to decrease the content of anti nutritive compounds, and to add new flavours without knowing the biochemistry behind these phenomena. Barley malting is the most widely known controlled germination process, used to produce malt for brewing purposes and food applications (Anu *et al*., 2004). India is the second largest producer of sorghum worldwide, and has the largest area under the crop. It occupies around 11 million ha in the semi-arid regions of the country and is the third most important food grain. Sorghum Stover is widely used as fodder and it often gains importance over grain in certain regions, particularly where growing conditions are unfavorable. The major states growing rainy-season sorghum are Karnataka, Madhya Pradesh, and Maharashtra, which together share 63% of the area and 77% of the production. Maharashtra, Karnataka, and Andhra Pradesh together share 93% of the area under postrainy-season sorghum (Kleih *et al*., 2007). Sorghum (Sorghum bicolor L. Moench) is an important source of dietary energy and a main food staple in semi-arid regions of Africa and Asia (Ezeogu *et al*., 2005).

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Due to its drought tolerance and adaptation attributes, this grain can be grown in those areas where agricultural and environmental conditions are unfavourable for the production of other crops. Sorghum is considered the world's fifth most important cereal after wheat, rice, maize, and barley (Serna and Rooney, 1995). In the United States, sorghum utilization directly for human foods is very limited, but with potential to increase (e.g. white food-type sorghum flour has been introduced in gluten-free products such as breads and cookies). Moreover, some specialty sorghums high in tannins have recently shown high antioxidant activities comparable to those of high-antioxidant fruits like blueberries and plums (Awika et al., 2003); giving sorghum an opportunity in functional food markets. Sorghum generally has the lowest starch digestibility compared to other cereals (Zhang and Hamaker, 1998).

MATERIALS AND METHODS

Procurement of Raw Material

Freshly harvested good quality raw materials of barley was procured from the local market of Sangrur, Punjab and cleaned in unit operation laboratory by using instruments like aspirator, grader etc and also by manual observation.

Germination of grains

Germination of Sorghum seeds were carried out as per the method described by (Arora *et al*., 2009).

Comparative chemical (proximate) analysis of Germinated and ungerminated Sorghum flour

All the comparative parameters for Sorghum like Moisture content, Ash content , Total carbohydrate content, reducing sugar, Starch content, Protein estimation Amylose content, Estimation of Crude Fibre, Fat content(A.O.A.C. 1980)was studied as protocol given by (Rangana 1986).

Physical Characteristics of flours of germinated and ungerminated grains of Soyabean

The Physical property of germinated and ungerminated grains of soyabean with the following parameters was determined. Water binding capacity (WBC) as the method described by (Yamazaki, 1953). Water Solubility Index (WSI) (Iwe, 1998), Oil binding capacity (OBC) (Yamazaki, 1953)

Viscosity of flours

The Brookfield rotational viscometer (Model LVT2, Brookfield Engineering Lab, Stoughton, Mass, USA) has been successfully applied to analyze rheology of pastes, colloidal suspensions and solutions (Sikdar and Ore, 1979). Flow properties of different composition porridges were determined according to a standard method of ISI-17-Ie. Apparent viscosity (μ_a) of flours of germinated and ungerminated grains of sorghum was determined using Brookfield viscometer with spindle No.1 at room temperature at different rpm (6, 12, 30 and 60). Flour samples were taken about 200ml in 250ml beaker and apparent viscosity (μ_a) in mPas was calculated by multiplying the dial reading at different rpm (6, 12, 30 and 60) of the Brookfield viscometer with the factors (10, 5, 2, and 1),respectively, as described in the manual of LVT Brookfield viscometer.

Falling number

Moisture test on a wheat sample that has been selected and ground is done first. A 7 gm ground sample, based on a 14% moisture basis, is used for the falling number test. Distilled water added to the ground sample in a falling number test tube. The ground wheat and water mixture is thoroughly shaken, forming slurry. A stirrer is placed in each falling number tube. Tubes containing slurry are immersed in the boiling water-bath of the falling number apparatus. The slurry is stirred with the stirrer for 60 sec. then stirrer is allowed to drop by its own weight through the ground flour of sorghum and water slurry. The total time in seconds it takes the stirrer to reach the bottom including the 60 seconds stirring time is the falling number result, which reflects the sprout damage in the sample. The falling number reading is then recorded.

Results and Discussion

In sorghum flour it was observed that the physical characteristics of sorghum in germinated and ungerminated vary as shown in Table.1. And the same way the physical property of was determined shown in Table.2.

Table 1. Chemical composition of ungerminated and germinated flours of sorghum

Samples → / (%) ↓	Ungerminated Sorghum Flour	Germinated Sorghum Flour
Moisture	9.9±0.27^b	10.2±0.28^a
Ash	1.79±0.12^b	1.39±0.11^a
Crude fiber	3.59±0.24^b	6.51±0.20^a
Carbohydrate	70.02±0.25^b	60.04±0.28^a
Total sugar	8.92±0.27^a	11.98±0.25^b
Reducing sugar	2.81±0.24^a	3.82±0.22^b
Non-reducing	6.11±0.23^a	8.16±0.21^b
Starch	65.2±0.23^b	58.1±0.26^a
Amylose	11.5±0.27^a	15.8±0.23^b
Amylopectin	53.7±0.27^b	42.3±0.28^a
Protein	7.25±0.27^a	9.85±0.28^b
Falling Number	365±0.29^b	70±0.28^a
Fat	6±0.27^b	4±0.24^a

Values are mean of 3 determination ± S.D. a to e character show significant difference in each row (P≤ 0.05)

Table 2. Physical (flour) properties ungerminated and germinated flours of Sorghum

Samples		Sorghum (u)	Sorghum (g)
Particle size (µm)		0.029	0.031
WAI (%)		121.6	129.6
WSI (%)		14	17
OAC (%)		3.78	3.17
Viscosity (cP)		30	21
Colour	(Yellow)	1.6	1.3
	(Red)	1.1	0.8
	(Blue)	0.8	0.3
	(TCU)	7.1	5.3

Samples in duplicate were taken and average values are reported u= ungerminated, g=germinated

It indicates that the moisture content of ungerminated and germinated flour samples of sorghum varied between 9.9 % to 10.2 % (wb) means moisture content was increased significantly after germination same as in case of soyabean. This finding is similar to the results reported by (Khatoon and Prakash, 2006) in germinated legumes (soyabean). As germination proceeds, legumes took up water from the surrounding in order for the metabolic process to commence. Dry legumes absorb water rapidly, influenced by the structure of the legume. The increase in water uptake with time is due to the increasing number of cells within the seed becoming hydrated (Nonogaki *et al.,* 2010). Germination of sorghum also led to decrease in ash content of germinated flour (1.39) than ungerminated sorghum flour (1.59) as shown in Table 2.

The decrease in ash content represents loss in minerals due to rootlet and washing of the sorghum in water to reduce the sour smell during the period of germination. These results are completely in agreement with results by (Tatsadjieu *et al*., 2004). Table 2 indicated that the total carbohydrate, total sugar, reducing and non-reducing sugar contents of sorghum flour as affected by soaking, germination and heating treatments. The soaking, germination and heating treatments given to sorghum grains decreased the total carbohydrate contents 70.2 % to 60.4 %.This was because of active respiration process during soaking and germination. On the other hand, soaking, germination and heating increased the reducing 2.81% to 3.82%, non-reducing 6.11% to 8.16 % and total sugars 8.92% to 11.98 %.

The sorghum contains maltose, glucose and fructose but during germination the level of germination gets increased because of conversion of maltose and fructose to glucose, due to activities of α-amylase and β-amylase enzymes, which increase with soaking and subsequent germination. Srivastva *et al*. (1988) also reported an increase in amylase activity during soaking and subsequent germination of pigeon pea. The results of soaking, germination and heating related with decrease in total carbohydrate and increase in sugars (total, reducing and non-reducing) are in agreement with those of germination effect study by (Tatsadjieu *et al*., 2004) and germination effect study on sorghum by (Neelam and Chauhan**,** 1990). The biological reactions involved in the germination are dependent on the temperature, because the enzymes involved have ranges of action that will retard or accelerate seed germination (Bewley and Black, 1994). The velocity in which the enzymes carry out their functions will interfere in the degrading of the reserved carbohydrates and ATP production, which will be used in forming proteins and other metabolites that originate tissues and cellular compounds (Mayer and Poljakoff-Mayber, 1989) that culminate with the protrusion of the rootlets and consequent seedling established (Copeland and Mcdonald, 1995; Marcos Filho, 2005).The protein and fat contents in sorghum as affected by soaking, germination and heating are given in Table 2 The germination of sorghum had an increasing effect on protein content 7.25 % to 9.85 %. (Tatsadjieu *et al*., 2004) reported that there is increase in protein content during prolonged germination of sorghum and (Khader,1983) also reported increase in protein content after germination. The fat content in present study decreased from 6 % to 4 % after soaking, germination (96hrs) and heating and this is due to increased activity of lipase enzyme. Similar results of decrease in fat content after soaking, prolonged germination and heating has been reported by several authors (Kaukovirta *et al*., 1993; Dibofori *et al*., 1994). Similarly the results of soaking, germination and heating related with decrease in fat and increase in protein are in agreement with those of (Dogra *et al*., 2001).

Crude fibre was increased in germinated sorghum from 3.59 % to 6.51 % Table 2. (Muyanja *et al*., 2001) reported that the crude fiber content increases during germination of millet grains. In germinated rice, the amount of crude fibre was contributed by the presence of bran layer, an outer layer of rice that contained fibre (Ohtsubo *et al*., 2005). Study by (Azizah and Zainon, 1997) demonstrated that crude fibre was decreased in soaked peanut and mung bean, but conversely increased in soaked rice and soybean. This indicates that germination process affect the level of crude fibre during the period of soaking before the actual phase of germination. Therefore, Studies have shown that intake of legumes have many health effects in controlling and preventing metabolic diseases such as diabetes mellitus and coronary heart diseases (Slavin *et al*., 1997; Liu *et al*., 1999). Combination of whole grain and legume powder in coronary artery disease patients without diabetes mellitus can reduce fasting levels of glucose and insulin (Jang *et al*., 2001). Germination meanwhile, altered the biochemical composition of legumes. Decrease of carbohydrate level is beneficial to diabetes mellitus patients. In addition, increase of total dietary fiber and decrease of fat content can give benefit to people with cardiovascular disease and hypercholesterolemia.

Table 2 indicated that the starch content of sorghum decreased from 65.2 % to 58.1% during soaking, germination (96 hrs) and heating. The increased α- amylase and β-amylase activities correspond with the decrease in the starch content, increase in amylose content from 11.5% to 15.8% and decrease in amylopectin from 53.7 % to 42.3 % in germinated soyabean flour and these results are in agreement with those of (Sharma *et al*., 2007). Palmer, (1989) reported that the germination of cereal grains caused extensive changes in the structure and composition of major macromolecular components of the grains. Since gelatinization rates are related to starch composition and structure, the extent of starch modification during grain germination may influence rates of gelatinization. Therefore, the small increase in gelatinization rates for starches from the out-of-steep through to the four day germinated grains at 50°C assay temperature may suggest small improvements in starch degradability due possibly to differences in the degree of modification of starch structure and composition. Changes such as these have been reported by (Glennie *et al*., 1984) in the structure of sorghum endosperm starch during germination and are also consistent with similar observations on starch from germinating barley grains (MacGregor and Matsuo, 1982).

The Pertson Falling Number apparatus was designed to assess the gelatinization of starch and its subsequent hydrolysis by alpha amylase. The ability of a sorghum grain to convert its own starch to low molecular weight sugars increases during the germination period due to the production of α and β-amylases. While starch contributes a very high viscosity to a ungerminated grain flour, the low molecular weight sugars contribute far less in germinated flour. The Pertson Falling Number apparatus measures this viscosity and assesses the ease with which starch can be converted to sugars during germination. Table 2 shows the effect of germination on the Falling Number assessment of sorghum flour of germinated and germinated grains. No exogenous enzymes were added to these experiments so that at casting the grain was not able to convert its own starch content to sugars.

Thus during the soaking, germination and heating stage the starch was gelatinized but without endogenous amylases present, and with the endosperm almost totally unmodified, the plunger was not able to fall through the slurry. After 12 hrs soaking, 96 hrs germination and heating treatment, there was sufficient modification to the grain, and sufficient enzymatic activity to convert the starch, and the plunger was able to fall quite rapidly through the gelatinized starch. After 96 hrs germination coinciding with considerable modification of the endosperm and development of enzymatic potential, the Falling Number was reduced to a minimum level i.e. from 365 to 70. The changes associated with germination are important for improving the nutritional value of the sorghum grain flour, and clearly it is possible to measure these changes with the Pertson Falling Number apparatus. These results are in agreement with results obtained through the study by (Sarah and Robert, 1991). Particle size of the ungerminated flours of sorghum increased after germination than ungerminated grains flour, as shown in Table 2 and also showed that the WAI of ungerminated grains flour of Sorghum increased from 121.6 % to 129.6 % and after soaking (12 hrs), germination (96 hrs) and heating.

The WAI of germinated grains got increased due increased protein content during germination since protein get increased the protein structure then hold maximum water by binding water molecules in its structure so therefore WSI increase after germination, these results are in agreement with the results obtained by (Cira-Chavez *et al*., 2009). Table 2 indicated that WSI (water solubility index) of ungerminated flour of sorghum increase from 14 % to 17 % respectively after soaking (12hrs), germination(96 hrrs) and heating of grains flour, with the fact that during the germination process the carbohydrate content decreased as a result of hydrolysis by the amylase enzymes. The increase in WSI with germination is of significance since it gives an indication that germination can be used to increase the amount of soluble materials, such as starch and amino acids, which can be easily digestible (Pelembe *et al*., 2000). OAC (Oil Absorption Capacity) of ungerminated grain flours of sorghum were decreased after 12 hrs soaking, 96 hrs germination and heating, from 3.78 % to 3.17 % respectively. In faba-bean flour protein content increases, WAI increases and OAC decreases after germination in the same trend is also exist for above all the grain so; these results are totally in agreement with (Rahma, 1988). Viscosity determination of germinated flour is important because it is one of the physicochemical attributes of flour content in hydrolytic enzymes. The results obtained were predicted because the decrease in starch content would result in less gelatinization occurring and hence decrease in the viscosity of all three flours of sorghum grains as shown in Table 2 i.e. in sorghum 30 to 21 cP.

The decrease in the viscosity of the flour was due to the action on the starch by hydrolyzing enzymes that were produced during germination. Starch breakdown proceeds by the combined actions of α-amylase, debranching enzyme (pullulanase like enzyme), β-amylase and α-glucosidase in germinated cereal seeds (Zeeman *et al*., 2007). (Sumathi *et al*., 1995) reported lower viscosities in malted legumes with corresponding increased in amylase activity. Colour of flours of ungerminated and germinated grains of sorghum grains were measured by using Lovibond tintometer and reading are as shown in Table 2 indicated that tcu (total colour units) of ungerminated flour decreased in case of sorghum flour tcu from 7.1 to 5.3, Yellowness decreased from 1.6 to 1.3 and Redness from 1.1 to 0.8 this is due to decrease in phenolic compounds like tannin this results are in agreement with (Dicko, 2005).

Conclusion

In the present study germination of sorghum was carried out under the controlled conditions of soaking, germination and heating. To get best results nutritional point of view and to get all the grains germinated at their optimum capacity germination was carried out on heat and trial method for all the grains at different soaking and germination time, finally the best results were obtained at 12hrs soaking time and 96 hrs germination time for sorghum grains so soaking was carried out for 12hrs and kept for germination up-to 96 hrs. Then these germinated grains were heated to stop the enzyme activities and to maintain the moisture content and we get finally the germinated grains then these grains were grounded into two types of flour having 60 mesh size particles and 25 mesh size particles. The fine flour of 60 mesh-size was evaluated for its chemical (proximate) composition like moisture content, ash content, carbohydrate, total sugar, reducing sugar, non-reducing sugar, starch, amylose, amylopectin, protein, fat and falling number, and also physiochemical properties like colour, water absorption index, water solubility index, oil binding capacity and particle size. It has been observed that chemical composition and physicochemical properties were significantly affected upon soaking (12hrs), germination (96 hrs) and heating to grains

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