Asian Food Science Journal

Volume 22, Issue 10, Page 60-69, 2023; Article no.AFSJ.107111
ISSN: 2581-7752

Physico-chemical Characteristics and the Effects of Processing Methods on the Nutritional and Anti-nutritional Quality of Soybean (*Glycine max* (L.) Merrill)

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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/AFSJ/2023/v22i10673

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/107111

Original Research Article

Received: 02/08/2023
Accepted: 04/10/2023
Published: 09/10/2023

ABSTRACT

The present investigation was carried out to determine the physico-chemical characteristics and effects of processing methods on the nutritional and anti-nutritional quality of soybeans. Soybean seeds were analysed using physico-chemical approaches, in order to obtain a detailed profile on these qualities. The effects of processing methods on the nutritional and anti-nutritional quality of

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soybean had an impact on the nutritional and anti-nutritional values. Soybeans were subjected to different processing methods which were sorted, washed, dried, and milled into flour (Sample A-Control), soaked in water (1:3) for 12h, mechanically dried at 60 ± 2 ^{o}C for 10 h and milled into flour (Sample B), soaked in water (1:3) for 12h, sprouted 72 h, mechanically-dried at 60 ± 2 ^{o}C for 10 h, roasted for 3 min and milled into flour (Sample C), boiled for 30 min in an open lid, mechanically-dried at 60 ± 2 ^{o}C for 10 h, roasted for 3 min and milled into flour (Sample D). The study revealed that raw soybean seeds had 90.43 ±3.93 g seed weight, 6.31 ± 0.41 mm length, 5.50 ± 0.29 mm breadth,4.58 ± 0.35 mm height, 0.88 ± 0.04 mm sphericity, 753.01 ± 6.62 kg/ m^3 bulk density, 1181.03 ± 11.72 kg/ m^3 true density, 36.33 ± 0.79 % porosity, 0.13 ± 0.005 g/seed hydration capacity, 1.25 ± 0.07 hydration index, 0.12 ± 0.01 mL swelling capacity, 1.62 ± 0.05 swelling index. The colour was recorded to be (L* 59.52, a* 8.97, b* 34.01), Chroma (c*) 35.17, and hue angle (h^{o}) 9.84. After processing, moisture content increased (10.61 - 12.43 %), crude protein (42.97– 47.87 %), crude fibre (9.44 - 11.57 %), ascorbic acid (5.38 - 11.65 mg/ 100 g), and ash content (4.84-5.99 %) while total carbohydrates and total energy decreased significantly (17.70 - 15.92 %) and (439.69 - 397.82 %), respectively. Similarly, the phytic acid content decreased from 8.12 to 5.19 mg/100 g while the tannin decreased from 25.34 to 18.57 % and the protease inhibitor decreased from 7.12 to 5.01 %. The overall results of the current study revealed that the processing methods of soybeans had an impact on the nutritional and anti-nutritional values. Further, the study showed that processing methods can significantly improve the nutritional qualities of soybeans while substantially reducing their anti-nutritional properties, thereby boosting the nutrients' bioavailability.

Keywords: physico-chemical characteristics; processing methods; nutritional values; anti-nutritional quality; soybean.

1. INTRODUCTION

“Recent research has shown that legume consumption has a variety of health benefits, including lowering the risk of cardiovascular disease, aiding in diabetes treatment, managing body weight, preventing cancer, and decreasing inflammation” [1]. “Legumes are also known to contain a variety of bioactive substances such as lectins, saponins, enzyme inhibitors, phytates, polyphenols (tannins), and oxalate” [2]. These bioactive substances are secondary metabolites that plants produce largely to protect themselves from harmful environmental circumstances [3], whereas others are reserve compounds, such as defense proteins (Bowman-Birk inhibitors and Kunitz inhibitors), which are stored in seeds as energy pools in preparation for germination [4]. “The effects of these chemicals might be either good or unfavorable'' [4]. As a result, depending on the biochemical and physiological aspects, as well as their concentrations, they might have both positive and detrimental effects.

Soybean is among the leguminous crops cultivated worldwide for food, feed, and oil [5]. “Soybean output in the world is around 176.6 million tons per year, with an average yield of 2.8 t/ha” [6]. It is recognized as the Queen, Golden, and Miracle of all leguminous crops because it has the maximum amount of protein, lipids, vitamins, and minerals. The protein quality of soybeans can be compared to animal protein sources such as meat and milk [7]. “Soybean contains about 40 - 45% proteins and 18 - 22% oil and is a rich source of vitamins and minerals” [8]. “Soy milk is a rich source of calcium, which is useful for vegetarians and people who are lactose intolerant, unable to fully digest dairy products” [9]. In addition, calcium from soy milk can be used to prevent osteoporosis.

“Raw soybeans contain several nutritional factors such as trypsin inhibitors, lectins, saponins, enzyme inhibitors, phytates, polyphenols (tannins), and oxalate which reduce the nutritional value of legumes and cause health problems for both humans and animals when they are consumed in large quantities” [10]. “Trypsin inhibitors can block either trypsin or chymotrypsin, lowering dietary protein breakdown, amino acid absorption, and hence digestibility” [11]. “These anti-nutrients should be eliminated to increase the nutritional content and sensory appeal of legumes for successful usage as prospective human food. Processing procedures can also increase the nutritional value of soybeans by enhancing the bioavailability of amino acids, vitamins, and protein digestibility” [12]. Okagbare and Akpodiete [13] also reported that seed treatment methods to remove anti-nutrient factors, were a major challenge for most farmers. Since the legumes and pulses are good and cheap source

of protein and other nutrients but are compromised with antinutritional factors. Therefore, more research on legumes and pulses are recommended to determine the best processing method with minimum acceptable level of antinutritional factors for better availability of nutrients for absorption.

2. MATERIALS AND METHODS

The current study was carried out at the Department of Food Science and Technology, College of Horticulture, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-173230, Solan- Himachal Pradesh (HP), India, to investigate nutritional quality and alternative techniques of processing soybean seeds. Yellow soybean seeds (20.00 kg) were bought from the Solan local market. The chemicals and reagents utilized in this study were of analytical grade and were obtained from Loba Chemie, International Scientific and Surgicals in Solan (HP), India. Polyethylene terephthalate (PET) containers were also provided by the same supplier. Three replicates were used for each treatment and analysis, and the results were computed on dry-weight basis. This study attempts to evaluate the impact of processing methods on the nutritional and anti-nutritional value of soybeans.

2.1 Physical Characteristics

2.1.1 Seed weight

In three replications, 1000 soybean seeds were counted and weighed. The average weight was computed and expressed in grams per thousand seeds.

2.1.2 Seed dimensions

Using a digital Vernier calliper NFSOFC brand, the length, breadth, and thickness of 10 randomly chosen soybean seeds were measured. The mean values were computed and reported in millimeters.

2.1.3 Sphericity

Mohesenin's method [14] was used to examine the sphericity of 10 randomly chosen soybean seeds. From lot of 20 kg soybean seeds 10 seeds were randomly chosen to calculate the sphericity using the formula here under.

$$\text{Sphericity } (\Phi) = \frac{(\text{LWT})1/3}{\text{L}}$$

L=length of seed
W= width of seed
T=Thickness of seed

2.1.4 Bulk density

The bulk density of soybean seeds was determined using the technique recommended by Varnamkhasti et al. [15]. The preset volume of the empty beaker was filled with seeds. To close the largest air gap possible, the beaker was tapped. The formula below was used to calculate the density of the seeds needed to fill the beaker:

$$\text{Bulk density (kg/m}^3) = \frac{\text{Weight of seeds}}{\text{Total volume}}$$

2.1.5 True density

The real density of the seeds was assessed using the toluene (C_7H_8) displacement technique, as described in Pradhan et al. [16]. The volume of 50 soybean seeds was calculated by pouring them into a graduated 50 mL cylinder that held 25 mL of toluene. It was noted that the toluene level increased. Following that, true density was determined using the provided formula and represented as kg/m^3.

$$\text{True density (kg/m}^3) = \frac{\text{Weight of seeds}}{\text{Volume of seeds}}$$

2.1.6 Porosity

By using the formula proposed by Mohsenin [14] and based on the estimates on bulk and real densities, the porosity of seeds was determined. The percent porosity was calculated using the following formula;

$$\text{Porosity (\%)} = 1\text{-} \frac{\text{Bulk density}}{\text{True density}}\ x100$$

2.1.7 Hydration capacity

For the analysis of the hydration capacity of seeds, the method suggested by Sood et al. [17] was used. After being weighed, 50 seeds were incubated in a conical flask (150.0 mL) filled with water (100.0 mL). The excess water was removed from the flask after it had been left at room temperature for 24 hours, and the seeds were dried by wiping them with absorbent paper. In order to determine the hydration capacity, the enlarged seeds were re-weighed. The equation is given below:

Hydration capacity per seed (g/seed) = (W of seeds after soaking (g)-W of seeds before soaking (g))/(Number of seeds)

2.1.8 Hydration index

According to Sood et al. [17], the hydration index of the seed was calculated by dividing its capacity to retain water by its weight.

$$\text{Hydration index} = \frac{\text{Hydration capacity per seed}}{\text{Weight of one seed}}$$

2.1.9 Swelling capacity

Distilled Water (50.0 mL) was put into a graduated cylinder (100.0 mL) and 50 soybean seeds were inserted. It was observed the quantity of both raw and soaked seedsThe volume of raw and soaked seeds was noted (Sood et al. [17]. The following formula was used to evaluate the swelling capacity value:

Swelling capacity per seed (mL/seed) = (Volume of seeds after soaking-Volume of seeds before soaking)/(Number of seeds)

2.1.10 Swelling index

According to Sood et al. [17], the swelling index of the seed was calculated by dividing the swelling capacity per seed by the volume per seed.

$$\text{Swelling index} = \frac{\text{Swelling capacity per seed}}{\text{Volume of one seed}}$$

2.1.11 Colour

The colour of soybean flour was measured in a Lovibond Colour Tintometer (Model PFX-I series) spectrocolourimeter in which RYBN colour units were obtained along with Commission Internationale de l'Éclairage (CIE) readings (L*, a* and b* values). Each sample was measured three times for colour [18]. Changes in colour (Δ E), chroma (C*), and hue angle (h^o) were calculated by the formula suggested by Goswami et al. [19].

$$\text{Chroma} = \sqrt{a^2 + b^2}$$

$$\text{Hue angle} = (h^o) = \tan^{-1}\left(\frac{b}{a}\right)$$

2.2 Sample Preparation

Different processing methods were employed to produce soybean flour. To germinate soybeans, the seeds were cleaned, washed and soaked in water (1:3) for 12 hours. The seeds were removed and germinated by spreading the seeds on a germination box (brand ??). The box was sprinkled with water twice a day until the seeds began to germinate. The germinated seeds were dried in oven (mention the brand of the oven and time -temperature combination for oven drying), roasted and ground into flour. Brief description of soybean seed samples processing is shown in Table 1.

2.3 Chemical Characteristics

The technique recommended by AOAC [20] was used to obtain the moisture content (%), ash content (%) and protein content (%). The AOAC [21] technique was used to assess crude fibre, and the AOAC [22] method was used to determine crude fat. The AOAC [23] technique's differential approach was used to compute total energy (Kcal/100 g) and total carbohydrates (%). β-carotene content (mg/100 g) was determined using the Ranganna [18] process. AOAC [24] method was used to analyse the ascorbic acid content.

2.4 Determination of Anti-Nutritional Factors

Tannin was measured using the gravimetric method described by Makkar et al. [25]. A 0.2 g was milled to pass 750 micron test sieve and extracted with 10 mL methanol by vortex mixing for 20 min in rotating screw cap tubes (13 x 100 mm). The mixture was then centrifuged for 10 minutes at 3500 revolution per minute (rpm)

Table 1. Soybean seeds processing methods

Sample	Processing Description
Sample A	Control (unprocessed; Soybean seeds sorting, washing, drying and milling into flour)
Sample B	Soybean seeds soaking in water for 12 h, mechanically drying at 60 ± 2 ˚C for 10 h and milling into flour
Sample C	Soybean seeds soaking in water for 12 h, sprouted for 72 h, mechanically drying at 60 ± 2 ˚C for 10 h, roasting for 3 min and milling into flour
Sample D	Boiling the soybean seeds for 30 min in an open lid, mechanically drying at 60 ± 2 ˚C for 10 h, roast for 3 min and milling into flour

and the supernatant was used in the analysis. A 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 mL aliquots of catechin standard were dispensed into two sets of tubes and each sample was brought to 1.0 mL by the addition of methanol. Incubating the tubes in the water bath at 30 °C, 5 mL of the working vanillin reagent was added at 1 min interval to one set of standards, and 5 mL of the 4% HCl in methanol solution was added at 1 min intervals to the second set of standards. Sample extract was also treated as for the standard. The samples in a water bath were kept for 20 min at 30 °C, and the absorbance at 500 nm was read using Spectrophotometer. The absorbance of the blank was subtracted from the absorbance of the corresponding vanillin-containing sample. A standard curve was constructed (absorbance vs. catechin) and the linear portion of the curve was extrapolated to produce the standard curve. Using the sample absorbance data, the condensed tannin contents were estimated from the calibration curve

Phytate was identified using the method described by Young and Greaves [26]. A sample (2 g) was weighed and mixed in 50 mL of 3 per cent trichloroacetic acid for 30 min continuously with mechanical shaker. The extract was centrifuged at 8000 rpm for 10 min to separate the supernatant. Ten mL of supernatant was taken in another test tube in which 4 mL of ferric chloride solution was added (583 mg $FeCl_3$ in 100 mL 3 % TCA). The mass was heated in boiling water bath for 30 min followed by addition of 2 drops of 3 per cent sodium sulphate (prepared in 3 % TCA solution) with continuous heating for next 15 min. The mixture was centrifuged at 8000 rpm for 10 min to collect the precipitate. The obtained precipitate was washed twice using 20-25 mL of 3 per cent TCA, followed by boiling for 10 min and centrifugation (8000 rpm for 10 min). The precipitate was dispersed in water then 3 mL of 1.5 N NaOH was added and volume was made up to 30 mL. The solution was heated for 30 min and filtered using Whatman No. 1. The residue was washed with 60 mL hot distilled water and dissolved in 40 mL of hot 3.2 N nitric acid into 100 mL volumetric flask. The used filter paper was also washed several times and the volume was made up with distilled water. The phytate content was analysed by taking 5 mL of aliquot in another 100 mL volumetric flask. Distilled water (70 mL) was poured followed by addition of 20 mL of 1.5 M potassium thiocyanate. The volume was made up and optical density (OD) of the solution was recorded immediately in spectrophotometer at 480 nm. The standard curve for phytate content was developed using different concentrations of ferric nitrate and calculated as per the formula given below:

$$\text{Phytate content (mg/100 g)} = \frac{Conc.of\ Fex\ 15}{Weight\ of\ sample}$$

Protease inhibitor was estimated by Ladd and Butler (1972). The trypsin solution was obtained by mixing 250 mg of trypsin (Activity 300 units/mg seed powder) in 50 mL of 0.01M phosphate buffer with pH of 7.6. The sample (200 mg) was dissolved in 35 mL of trypsin solution and incubated at 37°C for 2 h with gentle shaking. The mixture was then centrifuged at 12000 rpm for 15 min and the precipitate was collected. The precipitate was suspended again in 10 mL 0.01M phosphate buffer followed by centrifugation. The obtained residue was dried overnight at 40 °C in hot air oven. The sample as well as the residue were analysed for total nitrogen by micro-Kjeldahl method. The trypsin digestibility was calculated by measuring the difference between the nitrogen in the sample and residue as per the formula stated below:

$$\text{Trypsin digestibility (\%)} = \frac{N\ in\ sample - N\ in\ residue}{N\ in\ sample}$$

2.5 Statistical Analysis

For all parameters done for the evaluation of effect of soybean processing, analysis was done in triplicate and mean values was calculated. Data obtained were subjected to statistical analysis using the software SPSS (IBM, Armonk, NY) version 20. Duncan's multiple range test (DMRT) was conducted for significant differences at a level if the associated P-values < 0.05.

3. RESULTS AND DISCUSSION

3.1 Physical Characteristics

When designing machinery and equipment for sorting, separating, transporting, processing, and storing soybeans, it is essential to consider their physical characteristics. Designing such equipment and machines without taking this into consideration may yield poor results. Therefore, determination of these features plays a crucial role. The physical characteristics of soybean seeds flour are listed in Table 2. The seed weight of thousand seeds was recorded to be 90.43 g which is lower than the value investigated by Puozaa et al. [5] and in conformity with the range by Sharma et al. [27]. The difference may be

attributed to soybean cultivars. The average length noted was 6.31 mm, which is lower than the range analysed by Kuzniar et al. [28] while the breadth was 5.50 mm which is lower than the range expressed by Kuzniar et al. [28]. The seed dimensions in the present study are almost near to the range given by Nwakonobi and Idike [29], Wandkar et al. [30], Kuzniar et al. [28] and Sumangala and Kulkarni [31].

Based on the soybean yellow variety as shown in Table 2, the measurement results indicated that the lightness value was recorded to be 59.52 which is lower than the range (76,94-85.81) analysed by Abadi et al. (2022). The difference may be due to particle size difference. The smaller the particle size, the greater the L value. Symbol a* indicates the colour range from green to red with (−a= greenness; + a= redness). The value of a* was analysed as 8.97, which showed the level of redness is higher as compared to the range investigated (1.10-2.04) by Abadi et al. (2022). The value of b* presents the colour range from yellow to blue with (−a= blueness; + a= yellowness). The value of b* or yellowness level (34.01) is in line with the range (32.44-37.07) of Abadi et al. (2022). The chroma investigated to be 35.17 which is within the range (32.74-37.29) as reported by Abadi et al. (2022). The value of Hue (9.84) was smaller than the range (87.01-88.67) reported in the study by Abadi et al. (2022). The difference may be due to particle size difference.

3.2 Chemical Characteristics

The results of traditional processing of soybean seeds had effects on nutritional characteristics as shown in Table 3. The moisture content increased significantly with the processing method in which sample C showed the highest value. The results are in line with the results of Pele et al. [32]. The increase in moisture content in sample C may be due to the absorption of soaking water into the seeds' coat during sprouting [33]. However, sample C is more susceptible to microbial spoilage than samples A, B and D. Food samples with lower moisture content have a longer shelf life and better product quality than food with higher moisture content [34]. "The results showed that there is a significant increase in the crude protein content of sample C as compared with the other samples, with sample A having the lowest protein content. The increase in the protein content of sample C could be due to sprouting which increased the bioavailability of the crude proteins, in the soybeans. The significantly high increase in the crude protein of sprouted soybean could be attributed to complex biochemical changes that occur during hydration and sprouting, which lead to the protein constituent being broken down by enzymes into simple compounds, that are used to make new compounds. The disappearance of starch during germination may be attributed by the increase in amylase and phosphorylase activity in respiratory metabolism which improved the component

Table 2. Physical characteristics of soybean seeds yellow variety

Physical parameters	Determined values
Seeds weight (g/1000 seeds)	90.43 ± 3.39
Length (mm)	6.31 ± 0.41
Breadth (mm)	5.50 ± 0.29
Height (mm)	4.58 ± 0.35
Sphericity (mm)	0.88 ± 0.04
Bulk density (kg/m^3)	752.01 ± 6.62
True density (kg/m^3)	1181.03 ± 11.72
Porosity (%)	36.33 ± 0.79
Hydration capacity (g/seed)	0.13 ± 0.05
Hydration index	1.25 ± 0.02
Swelling capacity (mL/seed)	0.12 ± 0.01
Swelling index	1.62 ± 0.05
Colour	
L*	59.52 ± 0.96
a*	8.97 ± 1.08
b*	34.01 ± 0.57
Chroma (c*)	35.17 ± 5.32
Hue angle (h^o)	9.84 ± 7.86

L=lightness; a*=redness and greenness; b*=yellowness and blueness*

of total crude protein" [35]. "The increase in crude protein content relative to sprouting is particularly significant from a nutritional standpoint as it would increase digestibility and absorption. The result however showed that there is no significant difference in the amount of protein in samples A and C, though soaking and sprouting significantly increase the amount of protein content in sample B and C when compared with sample A. The results showed that crude fat content significantly decreased in sample C, while there is a significantly high counts in samples D and A. Decrease in fat content may be due to the depletion of the fat stored that contributed to the catabolic activities of the seeds, during sprouting" [36]. Another reason could be due to biochemical reaction and dissociation of lipid complexes, as reported by Ragab et al. (2010). The implication of this however is that sample D will be more prone to rancidity than the other samples. A significant increase in crude fibre content in sample C is due to the soaking and sprouting processes, which could be attributed to the disappearance of starch.Germination promoted a significant decrease of resistant starch along with an increase of available starch percentage. Total dietary fiber contents increased during germination and improved insoluble/soluble dietary fiber ratio. This process produced an increase of total sugar content, mainly due to the rise of cellulosic glucose from metabolic reaction undergone during germination The trend was also reported by Sood et al. [17]. A significantly high decrease in total carbohydrates was observed in the soaked and germinated seed flour (sample C). This may be due to sprouting, carbohydrate was used as a source of energy for embryonic growth which could explain the changes in carbohydrates content after sprouting. Uppal and Bains [37] reported a 5.6% decrease and Jirapa et al. [38] reported a 2.34% decrease, in carbohydrate content after 24 h of sprouting, in cowpea (Vigna unguiculata). The results are in accordance with Pele et al. [31] who reported a decrease in carbohydrates in sprouted soybean seed flour. Soaking and germination increased the ascorbic acid content significantly in sample C, when compared to other samples. The increase in ascorbic acid may be due to the enzymatic hydrolysis of starch by amylases and diastases, which in turns increases the availability of glucose for the biosynthesis of ascorbic acid (Desai et al. 2010). The increase of ascorbic acid in different sprouted pulse seed flour has been reported by Shah et al. [39]. The β-carotene content of the present study was significantly different; with sample C having the lowest β-carotene and sample A with the highest β-carotene The lowest β-carotene content in sample C may be due to oxidative degradation by lipoxigenase and peroxidase A similar trend has been observed by Khyade and Jagtap [40] in germinated cowpea (Vigna unguiculata), black gram (*Vigna mungo*) chickpea (*Cicer arietinum*) and yellow mustard (Sinapis alba). Results showed that there is a significant difference in ash contents of the tested samples. There is a significant increase in the ash content of sample D while sample C marked the lowest value. The effect of treatment on the ash content showed higher significance on soaked and germinated seed flour, when compared to the control. Similar results were reported by Ranhotra et al. [41]. An increase in ash content may be due to increase in phytase activity during germination, which hydrolyzed the bond between the proteins, enzymes and minerals, to release the minerals (Chinma et al. [42]. The total energy of 466.22 Kcal/100 g was found to be highest (in sample D) and lowest in sample C (397.82 Kcal/100 g). Significant low energy in soaked and germinated soybean seeds (sample C) is due to the fact that fats and carbohydrates decreased with an increase in germination time indicating that germinated legumes had lower energy content because of low fat and carbohydrates. Uppal and Bains, [37] in which energy depends on those parameters, during calculation (differential method). Seed sprouting involves energy use, which is provided by the breakdown of starch to sugars, lipids to free fatty acids, resulting in a shift in nutrient profile.

3.3 Effects of Processing Methods on the Anti-Nutritional Properties of Soybeans Flour

The results of the effects of traditional processing methods on the anti-nutritional factors of soybeans are presented in Table 4. Results showed that there is a significant decrease in phytic acid content of the tested samples. Soaking and sprouting soybeans reduced phytic acid levels in sample C. Osman [43] also reported a reduction in phytic acid content in different processing methods (soaking, cooking and germination). Results showed that there was a significant difference in the tannin content of the samples. Tannin content was decreased in samples C, D and B as compared to sample A. this could be attributed to a significant effect of soaking, sprouting and roasting which

Table 3. Chemical characteristics of soybean seeds (yellow variety) after four different processing methods

Parameters	Sample A (control)	Sample B	Sample C	Sample D
Moisture content (%)	10.61 ± 0.55^{c}	11.76 ± 0.32^{b}	12.43 ± 0.21^{a}	10.95 ± 3.98^{c}
Crude protein (%)	42.97 ± 0.72^{c}	47.55 ± 3.54^{b}	47.87 ± 0.23^{a}	42.76 ± 0.12^{c}
Crude fat (%)	21.89 ± 0.56^{b}	19.45 ± 0.76^{c}	16.14 ± 0.27^{d}	22.78 ± 1.12^{a}
Crude fibre (%)	9.44 ± 0.08^{c}	10.22 ± 0.52^{b}	11.57 ± 0.27^{a}	9.17 ± 0.09^{c}
Total carbohydrates (%)	17.70 ± 0.80^{a}	16.37 ±1.34^{c}	15.92 ± 0.87^{d}	17.54 ± 0.35^{b}
Ascorbic acid (mg/100g)	5.38 ± 0.17^{c}	5.89 ± 0.75^{b}	11.65 ± 0.19^{a}	5.28 ± 0.05^{c}
β-carotene (mg/100 g)	2.05 ± 0.02^{a}	1.97 ± 0.04^{b}	1.59 ± 0.06^{c}	1.37 ± 0.07^{c}
Ash (%)	4.84 ± 0.27^{c}	5.03 ± 0.05^{b}	5.99 ± 1.34^{a}	4.76 ± 3.34^{c}
Total energy (Kcal /100 g)	439.69 ± 3.58^{b}	430.73 ± 4.32^{c}	397.82 ± 6.18^{d}	466.22 ± 2.87^{a}

Means sharing the same superscript letter in rows are not significantly different from each other (Dancan Multiple Range Test (DMRT), $p \leq 0.05$)

Table 4: Antinutritional factors s of soybean seeds yellow variety) after four different processing methods

Parameters	Sample A (control)	Sample B	Sample C	Sample D
Phytic acid (%)	8.12 ± 0.91^{a}	7.76 ± 0.15^{b}	5.19 ± 0.17^{d}	6.85 ± 0.11^{c}
Tannin (mg/100 g)	25.34 ± 0.34^{a}	23.55 ± 3.76^{b}	18.57 ± 0.13^{c}	23.26 ± 0.67^{b}
Protease inhibitor (%)	7.12 ± 0.88^{a}	6.95 ± 0.09^{b}	5.01 ± 0.54^{d}	6.55 ± 0.79^{c}

Means sharing the same superscript letter in rows are not significantly different from each other (DancanMultiple Range Test, $p \leq 0.05$)

deteriorated the tannins. The protease inhibitor of samples B, C and D had significantly decreased; due to soaking, sprouting and roasting steps, which are significant in its reduction [44, 45, 46, 47].

4. CONCLUSION

The study highlighted the impact of conventional processing methods on the nutritional and anti-nutritional qualities of soybeans. Soaking and germination decrease significantly crude fat, carbohydrates, β-carotene and total energy in soybean seed flour while increasing significantly moisture, crude protein, crude fibre, ascorbic acid and ash. Furthermore, the results showed that processing methods considerably decreased the anti-nutritional qualities of soybeans. Soaking and sprouting lowered significantly the total carbohydrates and fat which may be an advantage for overweight and obese people, who need to consume less carbohydrates and low-fat foods. The positive values in colour signify that the soybean seeds used in this study were of high quality.

ACKNOWLEDGEMENT

We are grateful and sincere to the Dr Yashwant Singh Parmar University College of Horticulture and Forestry in Himachal Pradesh, India, for providing all of the necessary facilities and technical support to accomplish this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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