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(RESEARCH ARTICLE)

Optimization of soybean pre-treatment processes for the improvement of their nutritional, biochemical and bioactive characteristics

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Abstract

Soybeans (Glycine max) are one of the most widely grown oilseeds in the world. Soybeans are processed into several products. However, during these transformation processes, the nutritional value of the beans can be greatly affected. Therefore, it was important to find optimal conditions under which soybeans can be processed while retaining their nutritional value. The objective of the study was therefore to improve the nutritional composition of soybeans while optimizing the different processing techniques. Thus, untreated (EN), dehulled (ED), sprouted (EG), roasted (ETO,) and distilled water soaked (ET) soybeans were used to determine the proximate, bioactive and anti-nutritional composition. Sprouted (EG) and dehulled (ED) beans were subjected to temperature and time factors respectively to determine the action of these factors on the nutritional composition of soybeans. The results show that the different types of samples are rich in protein (37.98±2.75 g/100g DM), fat (20.02±1.87 g/100g DM), potassium (1838.68±2.75 mg/100g DM), and magnesium (276.45±8.47 g/100g). Sprouted seeds (ED) and hulled seeds (ED) showed the best nutritional potential. The effect of soaking temperature on shelled seeds and the monitoring of germination at 24h, 48h, and 72h allowed for optimizing the nutritional properties of soybeans. Thus, the samples germinated at 24 h showed the highest energy value while the seeds germinated at 72 h are more suitable in terms of functional foods and the hulled soybeans soaked at 40°C have a high food potential. These data are very important in food industries and for possible formulations.

Keywords: Soybeans; Nutritional value; Optimization; Process technology

1. Introduction

Soybean (Glycine max) is a species of annual plant of the legume family (Fabaceae) that is more adaptable to climate and humidity. This plant is currently considered one of the most important oilseed crops all over the world [1]. It is a very important crop worldwide commonly grown for its edible bean, which has an important nutritional value and enormous nutritional properties. This bean is rich in total protein, dietary fiber, and starch [2]. It is a source of vegetable protein with high nutrition values. The mineral fraction of soybeans contains several types of minerals, the most important of which are: potassium, phosphorus, magnesium, calcium, and iron which perform essential functions in the body [3]. They would also contain important quantities of sucrose which would give them a sweet taste [4]. Soybean oil is rich in omega-6, omega-9, omega-3, and unsaturated fatty acids. This oil provides more than a quarter of the total edible oil produced globally [5]. In addition, soybeans contain several types of phenolic compounds such as isoflavones,

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tocopherols, and saponins that may reduce the risk of the major killer diseases, namely hormone-dependent cancers. All these nutritional properties explain the wide range of processed soy products. the soybean can be consumed raw, defatted to produce a protein animal feed, processed to produce meat and dairy substitutes, and fermented to produce products such as soy sauce [6]. It can also be made into cookies, soy, and milk [7]. This wide range of processing makes it an essential crop economically and has increased its production over the years. This increase in production would be due to its high nutritional value and health benefits [8]. Soybean cultivation is also of proven economic importance since its cultivation generated approximately US$ 12,647.000 in 2020 [9]. This makes it a substantial crop for many households around the world. Over and above its richness in nutrients, the soya bean has proven antioxidant and anti-inflammatory properties [1].

Food and nutrition security is a growing challenge worldwide. Cereal products can greatly contribute to achieving food security. Products such as soybeans that have many food technology capabilities sometimes undergo content changes during processing [10]. . Soybean proteins are especially highly valued in the food industry because of their essential amino acid content and their affordable cost [11]. Indeed, thermal, biological, and chemical operations largely influence the nutritional composition of plants such as soybeans. Recent studies have shown that the time of fermentation, germination, and roasting significantly affect the technological properties of cereals [12]. Other processes such as ultrasound have effects on the structure of the peptides that make up the soybean proteins [13]. It is therefore important to evaluate the effect of the different technological processes that soybeans undergo during processing. Thus, knowledge of the influence of each unit operation on the biochemical composition of the soybean will allow better orientation of its processing according to the characteristics of the expected final product. . This study was therefore conducted to evaluate the impact of certain processing methods on the nutritional composition of soybeans.

2. Material and methods

2.1. Plant materials

The soybeans were acquired from a model producer who benefits from the support of the technicians of the Ministry of Agriculture. They were collected between October and December 2021. They then underwent various technological treatments to evaluate the effect of these treatments on their nutritional properties to optimize the nutritional potential of soybeans.

2.2. Processing of soybeans for dosing

2.2.1. Untreated soybeans

Soybeans were used without treatment for the determination of the different assays. These samples have been coded "EN".

2.2.2. Flour of torrefied soybeans

Dried soybeans (400g) were roasted in a pan at 120°C for 20 mn [14]. These roasted almonds were cooled at room temperature for 4 hours before being ground. The flour obtained was stored in airtight containers and named ETO.

2.2.3. Uncoated soybeans

The dry soybeans were dehulled manually and ground with a blender and the flours were used for the different analyses. These samples have been coded "ED".

2.2.4. Soaked soybeans

The soybeans were soaked in distilled water for 12 hours. After draining they were dried in a ventilated dryer and then ground with a mixer. The flour obtained was used for the different analyses. In addition, the effect of soaking temperature on the nutritional composition was evaluated after soaking at different temperatures in distilled water. These samples have been coded "ET".

2.2.5. Sprouted soybeans

Soybeans were placed in pots containing clay and placed in a lighted chamber in which the temperature varied between 25°C and 30°C. After 72 h, the seeds at the beginning of germination were used for the determination of the various parameters. To follow the effect of germination on the proximate composition of soybeans, these seeds were taken at 24 h, 48 h, and 72 h of germination, and different parameters were evaluated. These samples have been coded "EG".

2.3. Physics and proximate, biochemical and minerals composition

The ash content was determined by using a muffle furnace at a temperature of 550°C for some time of 6 h according to AOAC, (2000) [15]. The water content and dry matter were determined by drying at 105 °C for 24 h in a steam room according to NF V 03-707 [16]. Total lipids were obtained using a Soxhlet extractor with hexane as solvent according to NF V 03-905 [17]. Crude proteins were determined by the Bradford method [18] with slight modifications by [19] Samples (500 mg) of soybeans flours were homogenized in 10 mL of 0.1 M NaCl, and the whole was stirred for 5 h at 150 rpm/min at 25°C. The extract was collected after centrifugation at 4400 rpm for 30 min at 4°C. To 50 µL of each extract was added 250 µL of Bradford reagent. After incubation for 2 min, absorbances are read at 595 nm. A standard curve (y =1.3138x + 0.0119; R^2 =0.999) was built using BSA as standard. Carbohydrate contents were determined by the phenol-sulfuric (5%) acid method [20] with few modifications. Absorbances are read on the spectrophotometer at 490 nm. Glucose was used as standard allowing to build a linear plot (y= 0.0107x + 0.9804; R2 = 0.998). The potential energy value was estimated using the Atwater coefficients. The calorific value of the sample is calculated [21] as follows:

$$\text{Energy value} = P \times 4\ \text{Kcal} + G \times 4\ \text{Kcal} + L \times 9\ \text{Kcal} = X\ \text{kcal}/100\ \text{g}$$

P, G, and L are the proportions of proteins, carbohydrates, and lipids, respectively.

The mineral content (K, Ca, Mg, Na, Fe, Mn, Zn, Cu) of soybeans was determined using a flame atomic absorption spectrophotometer. The content of these samples was determined using a calibration curve for each element measured.

2.4. Bioactive and anti-nutritional compounds

The total phenolic content was determined at 760 nm using gallic acid as a reference compound, using the Folin-Ciocalteu method as described by Singleton et al. (1965) with some modifications added by [22] . The total phenolics were expressed as mg of gallic acid equivalent per g of dry seed weight (mg GAE/g DM).

The total flavonoid content was determined at 415 nm using the method described by Arvouet-Grand et al (Arvouet-Grand et al., 1994). The total flavonoid content was determined on a quercetin calibration curve and expressed as mg of quercetin equivalents (QE) per g of dry seed weight (mg QE/g seeds DM).

2.5. Determination of phytate content

Phytate determination was based on a spectrophotometric assay using phytic acid as standard [23] . The assay was performed with 2.0 mL of Wade reagent (0.03% (w/v) $FeCl_3$ and 0.3% sulfosalicylic acid) and 3.0 mL of the eluted sample. The phytate content was determined at 500 nm using a spectrophotometer.

2.6. Statistical analysis

Graphs, calculations of the different concentrations, ANOVA, and principal component analyses were performed using Excel 2016 spreadsheet, and XLSTAT 2016.

3. Results and discussion

3.1. Proximate composition and bioactive contents comparison by extraction methods

The proximate composition, the mineral and bioactive contents of soybeans were determined by using them in different states. Thus, soybeans were dehulled, sprouted, roasted, and soaked in water. The meals of these different fractions were used for the analyses (Table1). Proximate composition, major nutrients, micronutrients, bioactive compounds, and anti-nutritional factors were determined for the different types of samples.

The determination of physicochemical parameters is extra important in food technology for preservation and primary processing needs. The ash content varied from 5.32±0.55 to 4.71±043 g/100g DM. Sprouted seeds presented the best ash percentage and the highest percentage was observed for soaked seeds. The moisture content of the seeds varied between 3.08±0.87 and 6.10±1.02%. As for the dry matter of the seeds, it varied from 93.89±2.04 and 96.82±1.78. The highest dry matter content was observed for torrefied seeds (ETO). The moisture content of the samples ranged from 3.08±0.87 to 6.10±1.02 % for the roasted (ETO) and soaked (ET) samples, respectively. In general, the mineral fraction of soybeans is quite high, suggesting that they contain a lot of mineral components. Soybeans contain very little water, which is very important especially since it is a cereal. Indeed, there is a negative correlation between the shelf life of cereal products and their moisture [24] . Thus, the lower the moisture content, the better the cereals store. This humidity, which is around 5 %, is below the threshold set by the FAO for the conservation of cereals. This standard is 13% for cereal products such as wheat and soybeans. Even if the humidity of the environment was high, the soybeans could be preserved without any problem. The roasted soybeans (ETO) would have the best storage ability because they had the lowest moisture content.

The major nutrient content of soybeans varied significantly with the different treatments (Table 1). Thus, the fat content varied between 18.94±2.01g/100g DM and 21.83±2.9g/100g DM respectively for soaked (ET) and roasted (ETO) seeds. Thus, heat treatment increases the fat content while soaking, which absorbs water, and slightly decreases the fat content of soybeans. The increase in temperature allows to substantially reduce the humidity and increase on the contrary certain constituents such as oils are less sensitive to the temperature increase. The oil extracted from soybeans contains several types of fatty acids, the most representative of which are oleic, stearic, palmitic, and linoleic acids which play important metabolic roles in the body [25] . Even if heat treatment does not reduce the overall fat content, it should be noted that it can affect the physicochemical parameters of the oils contained in these soybeans. Moreover, moderate heating does not modify the structure of fatty acids. Cherif & Slama, (2022) have shown that heating up to 150°C does not change the nature of fatty acids present in soybean oils. The results show that the other treatments did not affect the lipid content compared to the seeds that did not undergo any treatment. The total protein content varied between 33.20±3.45 g/100g DM for roasted seeds (ETO) and 39.66±3.45 g/100g DM for shelled seeds (ED). The treatments had an impact on the total protein content. Soya is an oleaginous plant very rich in proteins, so it is also referred to as poor man meat [3] . This significant protein content explains its transformation into meat substitutes widely appreciated by the population [6]. The literature reveals that the protein fraction of soybeans contains a large proportion of amino acids such as aspartic acid, glutamic acid, tyrosine, and arginine whose metabolic functions are no longer in question [26] . Untreated and only shelled beans had the highest protein content. Beans that underwent biological or thermal processing had much lower contents. For example, during germination, protein and carbohydrate reserves are transformed to be used by the seedling. Raw soybeans have a sweet taste [4] and this taste is due to the carbohydrates contained in the bean. These carbohydrates are generally sugars and starch. For carbohydrates content, shelled seeds showed the highest content which is 18.46±1.14 g/100g DM. We observe a significant decrease in the carbohydrate content for sprouted seeds (EG) (14.98±2.48 g/100g DM). This could be explained by the fact that germination is a biological process that requires a significant expenditure of energy. The carbohydrate reserves were thus converted into energy to allow the seed to germinate [27]. The contents of "major nutrients" gave energy values ranging from 381.27±8.98 KJ to 414.81±11.45 KJ. The shelled samples have the highest energy value, i.e., the shelled seeds have undergone very little alteration concerning major nutrients (ED).

The minerals quantified showed a notable variation for the different treatments. Soybeans contain several minerals among which potassium (K) and magnesium (Mg) are the most abundant. Indeed, for these two minerals, it is the untreated seeds that showed the best values, 2245.07±14.75 mg/100gDM and 494.68±5.21 mg/100g DM respectively for K and Mg. For sodium (Na) and iron (Fe), the best contents are obtained with the seeds subjected to germination. These contents are respectively 3.39±0.21 mg/100g DM and 9.0±1.23 mg/100g DM. The dehulled samples also showed the best content (7.53±0.42 mg/100g DM) of zinc (Zn). These results are similar to those of [28-29] n previous studies. A significant difference between the different types of samples was noted. In general, the germinated seeds (EG) presented the best contents in minerals. Minerals are considered to be essential in human nutrition. These minerals are essential to overall mental and physical well-being and are constituents of bone, teeth, tissue, muscle, blood, and nerve cells [30]. They also help in the maintenance of acid-base balance, the response of nerves to physiological stimulation, and blood clotting [31].

The different treatments of the soybeans had very little effect on the total phenolic and flavonoid contents. Thus, the total phenolic content oscillated between 7.79±1.41 mgGAE/100 DM and 10.60±0.96 mgGAE/100g DM. For the flavonoid content, the highest content was 5.67±0.12 mg QE/100g DM and the lowest content is 3.91±0.54 mg/QE100g DM. A variation is observed between the different samples. Sprouted seeds (EG) contained the highest levels of bioactive compounds while soaked seeds showed the lowest concentrations Total phenolics of medicinal plants also present interesting anti-inflammatory [32] antioxidant and antibacterial capacities, which allow them to fight effectively against diseases [32-33] . Their hydroxyl groups give them a capacity for scavenging especially free radicals [34]. According to the literature, flavonoids also had antimicrobial, antiviral, anti-allergenic, and anti-aging properties [35] . Also, it appears that flavonoids are a group of phenolic compounds very important for animal and human health because of the antioxidant and antitumor properties they possess [36].

Soybeans also contain anti-nutritional factors, namely phytates. The results show low levels of phytates which decrease with the different treatments. Thus, shelled seeds (ED) contain the highest levels (4.03±0.78 mgPAE/100g DM) followed respectively by untreated seeds, germinated seeds, and soaked seeds. The seeds having undergone the roasting (ETO) presented the lowest contents of anti-nutritional factors which is 2.71±0.67 mgPAE/100g DM. Phytic acid is also known to reduce the absorption of certain minerals such as divalent cations (copper, zinc, iron, etc.) [37].

Table 1 Composition of the different extraction methods

Parameters		ED	EN	EG	ETO	ET
Physics and proximate composition	Ash (g/100DM)	5.08±0.75 ^{ab}	5.04±.65 ^{b}	5.32±0.55 ^{a}	5.21±0.84 ^{ab}	4.71±043 ^{c}
	Humidity (%)	4.89±1.07 ^{b}	4.95± ^{b}	3.84±0.36 ^{c}	3.08±0.87 ^{d}	6.10±1.02 ^{a}
	Dry matter (%)	95.10±2.5 ^{b}	95.04±1.95 ^{b}	96.15±3.14 ^{a}	96.82±1.78 ^{a}	93.89±2.04 ^{c}
Biochemical compounds	Lipids (g/100DM)	20.25±1.78 ^{c}	20.05±1.93 ^{c}	20.66±2.51 ^{b}	21.83±2.9 ^{a}	18.94±2.01 ^{d}
	Proteins (g/100DM)	39.66±3.45 ^{a}	38.68±2.75 ^{a}	34.58±2.45 ^{a}	33.20±3.45 ^{a}	35.93±2.79 ^{a}
	Carbohydrates (g/100DM)	18.46±1.14 ^{a}	17.88±3.14 ^{a}	14.98±2.48 ^{c}	14.89±2.05 ^{c}	16.75±3.02 ^{b}
	Energy (KJ)	414.81±11.45 ^{a}	406.80±12.45 ^{ab}	384.26±9.45 ^{b}	388.88±13.17 ^{ab}	381.27±8.98 ^{b}
Micronutrients	Fe (mg/100gDM)	7.53±0.42 ^{b}	7.49±1.4 ^{b}	9.0±1.23 ^{a}	7.46±0.98 ^{b}	6.76±1.03 c
	Zn (mg/100gDM)	8.37±1.14 ^{a}	7.57±0.78 ^{b}	3.69±1.5 ^{e}	6.63±1.21 ^{c}	4.53±0.95 ^{d}
	K (mg/100gDM)	1720.45±22.14 ^{bc}	2245.07±14.75 ^{a}	1771.04±17.4 ^{b}	1624.32±20,02 ^{c}	1385.42±11,10 ^{d}
	Na (mg/100gDM)	3.39±0.21 ^{a}	2.92±0.45 ^{a}	3.42±0.64 ^{a}	3.13±0.33 ^{a}	2.74±0.47 ^{a}
	Mg (mg/100gDM)	337.74±6.4 ^{b}	494.68±5.21 ^{a}	120.94±4.12 ^{c}	110.07±6.45 ^{c}	329.57±9.15 ^{b}
Bioactives compounds	Total phenolics (gGAE/100gDM)	8.51±0.45 ^{b}	9.71±1.02 ^{a}	10.60±0.96 ^{a}	8.39±0.45 ^{b}	7.79±1.41 ^{b}
	Flavonoids (gQE/100gDM)	5.32±0.51 ^{a}	5.67±0.12 ^{a}	4.84±0.75 ^{a}	3.91±0.54 ^{a}	4.37±0.46 ^{a}
Antinutritional compounds	Phytates (PAE/100gDM)	4.03±0.78 ^{a}	3.55±0.62 ^{ab}	3.23±0.87 ^{bc}	2.71±0.67 ^{c}	3.06±0.15^{bc}

DM: Dry Matter; GAE: Galic Acid Equivalent; QE: quercetin equivalent; PAE: Phytic Acid Equivalent. A line with different letters, have statistically different values

3.2. Principal component analysis of different optimization methods

Principal component analysis reveals two distinct groups (Figure 1). The first group consists of parameters such as lipids, dry matter, total ash, and total phenolics. This group has a strong positive correlation with the sprouted samples (EG) and to a lesser extent with the roasted samples (ED). The second group consists of parameters such as Mg, carbohydrate, protein, phytate, Zn, and flavonoid contents, and also the energy value. These parameters are strongly positively correlated with the unhulled seeds (ED) and with the untreated seeds (EN). The soaked samples (ET) showed the lowest correlation concerning the nutritional parameters studied. On the contrary, they showed the highest moisture content compared to the other samples. This discriminatory test to determine the best treatment based on the parameters studied is very important. Thus, germination is the treatment that best improves the nutritional status of soybeans. All this is explicable because of the purely biological nature of germination which allows for activating of enzymatic processes and also proved the beneficial effects on the improvement of the physicochemical metabolism and the phenolic acid, It is necessary to point out that during germination the seed leaves the state of dormancy to approach an active life marked by the use of the reserves of macronutrients to carry out the metabolic functions. It has also been demonstrated that germination positively impacts the functional properties of soybeans while improving their ability to be transformed into soy milk [38] . Cookies made from sprouted soybeans were also the best among several cookies made from various soybean treatments [39]. The dehulled samples also showed interesting characteristics because they underwent very little modification of their biochemical content. Indeed, the seeds do not undergo any biological or thermal transformation, so the structure of the constituents is not affected. Its composition is thus very close to that of the not treated seeds. Considering these elements, we can say that sprouted seeds and hulled seeds have the best technological aptitudes. They have therefore been selected to optimize the optimal levels for food processing.

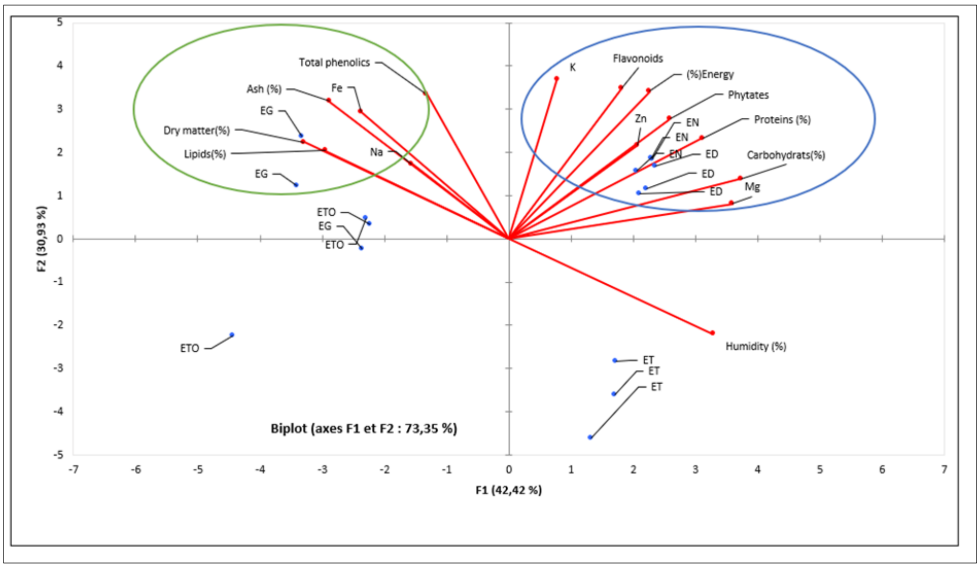

Figure 1 Principal component analysis of different optimization methods

3.3. Effect of soaking temperature on dehulled seeds

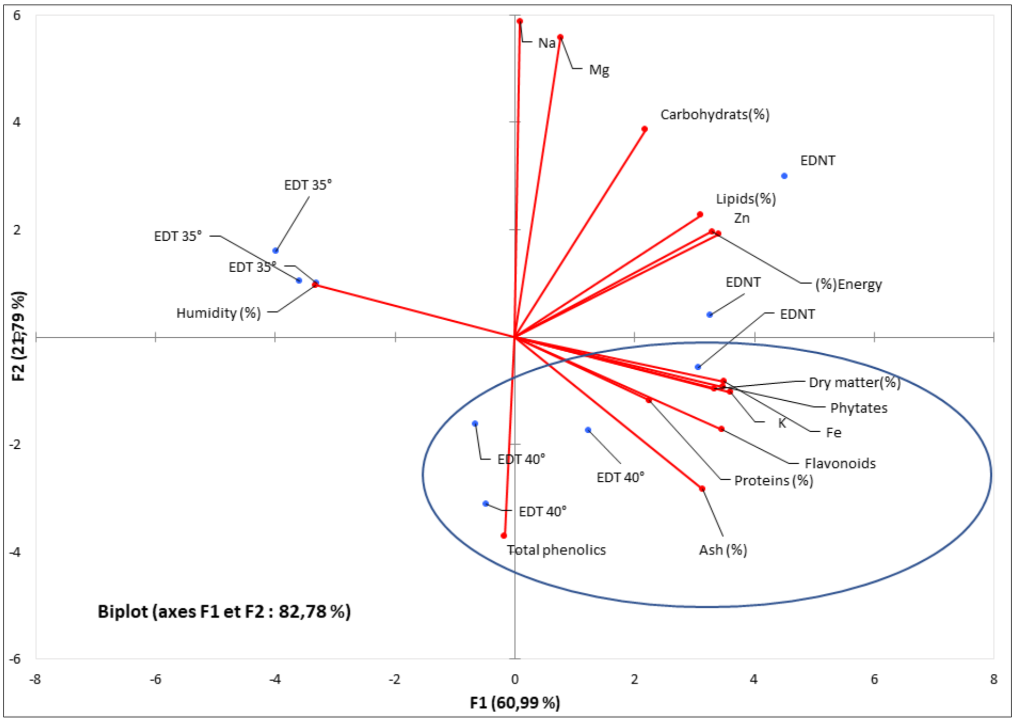

Figure 2 Effect of soaking temperature on dehulled seeds

To optimize the technological properties of the shelled seeds, they were soaked in water at different temperatures. One batch of shelled samples was not processed in the process. Temperature is an essential factor in technological processes. Temperature is a factor that greatly influences the nutritional constituents of raw materials in food processing. In the case of hulled soybeans, the results show that hulled soybeans soaked in distilled water at 40°C (EDT 40°) exhibited the best nutritional properties compared to hulled seeds soaked at 35°C (EDT 35°C) and unsoaked hulled seeds (EDNT) (Figure 2). The EDT 40° samples presented the best contents for most of the parameters such as total phenolic, total ash, protein, flavonoids, K, Fe, etc. The principal component analysis shows a strong correlation between the EDT 40°C sample and these parameters (Figure 2). Soaking at 35°C (EDT 35°C) is the sample with the least food advantage compared to other samples because only its moisture content is higher than that of the other processes.

Thus, to optimize the technological potential of shelled soybeans, soaking at 40°C. This is extremely important in the food industry as it allows processing operations to be carried out under optimal conditions that best retain nutritional properties. Previous studies have shown that temperatures between 35°C and 45°C were ideal processing temperatures to preserve and optimize their nutritional potential [40-41]. Ben Ahmed *et* al., (2016) showed that temperatures between 35°C and 55°C allowed an optimal extraction of phenolic compounds [42].

3.4. Effect of germination time on nutritional properties

Table 2 Effect of germination time on nutritional properties

Parameters		EG 24 h	EG 48 h	EG 72 h
Physics and proximate composition	Ash (g/100DM)	5.152±0.12 c	5.27±0.32 b	5.352±0.21 a
	Humidity (%)	4.430±0.11 a	4.425±0.23 a	3.516±0.235 b
	Dry matter (%)	95.570±2.25 b	95.575±2.15 b	96.484±1.715 a
Biochemical compounds	Lipids (g/100DM)	20.681±1.12 a	20.581±1.45 a	20.793±1.23 a
	Proteins (g/100DM)	38.28±2.12 a	35.604±2.12 b	34.260±1.78 c
	Carbohydrates (g/100DM)	15.280±1.55 a	15.157±1.021 b	14.899±1.24 c
	Energy (KJ)	400.367±14.45 a	388.272±13.45 b	383.776±11.79 c
Micronutrients	Fe (mg/100DM)	8.957±0.54 b	8.904±0.32 c	9.154±0.75 a
	Zn (mg/100gDM)	6.989±212 a	3.904±0.68 b	3.607±0.24 c
	K (mg/100gDM)	1589.92±32.25c	1683.5±21.51 b	1821.568±16.45 a
	Na (mg/100gDM)	3.61±0.45 a	3.388±0.35 a	2.96±0.42 a
	Mg (mg/100gDM)	461.901±8.8 a	113.55±10.155 c	124.857±12.5 b
Bioactives compounds	Total phenolics (gGAE/100gDM)	8.878±1.47 a	9.953±1.75 a	11.833±2.012 a
	Flavonoids (gQE/100gDM)	3.159±0.24 b	3.319±0.71 b	5.560±0654 a
Anti-nutritional compounds	Phytates (gPAE/100gDM)	3.967±0.24 a	3.258±1.02 ab	3.066±0.73 b

DM: Dry Matter. A line with different letters, have statistically different values

Germination is a biological process that can also impact the biochemical composition of cereals. Seed germination is the most critical stage in the life cycle of a plant [43]. The results show that the nutrient composition varies according to the germination time (Table 2). In general, it appears that the contents of major nutrients decrease slightly with time. Thus, the seeds subjected to germination during 24h (EG 24h) presented the best concentrations of major elements (proteins, carbohydrates, and fats). The microelement's contents also varied according to the germination time. For Zn and Mg, the 24h germinated sample showed the highest levels. Zinc content decreased considerably during the germination process. For iron and magnesium, the 72h germinated seed showed the highest concentrations without a significant variation compared to the other sample. When one confronts the various parameters, the samples of seeds germinated within 24h present the best in terms of coverage of the food needs. On the other hand, for functional food and micronutrients, the seeds germinated at 72h are the most suitable because they are very rich in minerals and bioactive compounds. A progressive decrease in phytate content is observed during germination. This content decreases from 3.967±0.24 gPAE/100 DM to 3.066±0.73 100Gpae DM (Table2). Germination can result in the digestion or reduction of protease inhibitors, phytic acid, and other anti-nutritional factors [44]. The breakdown of these macromolecular substances is beneficial for amino acid and protein composition. Amino acids and proteins are important precursors for the synthesis of vitamins, γ-aminobutyric acid, and rutin [45]. Also, germination at 72 hours allows for a significantly reduces the content of phytates which are nutritional factors [46]. Farzaneh et al. (2017) revealed that the highest amount of starch was observed in the malt resulting from the 3-day germination [47]. As a reminder, anti-nutritional factors prevent or decrease the bioavailability of certain minerals such as iron and zinc, etc. [14].

4. Conclusion

The effect of different treatments on the nutritional composition of soybeans allowed to select the treatment that best preserves the nutritional properties of soybeans. Taking into account all the parameters studied, it was found that sprouted beans had the best technological potential, followed by shelled beans. In general, soybeans are very rich in protein and fat. To optimize these two treatments to improve the nutritional value of processed soybean foods, time and temperature parameters were associated with them. It should be noted that the shelled seeds soaked in water at 40°C presented the best nutrient composition. For sprouted seeds, those sprouted for 24 hours produced the highest energy value. However, in terms of functional foods, the seeds germinated during 72 hours showed the best nutritional composition. This information is very important for the food industry in a world that is increasingly demanding in terms of nutrition.

Compliance with ethical standards

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Disclosure of conflict of interest

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Availability of data and materials

The datasets generated and/or analyzed during the study are available from the corresponding author on reasonable request.

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