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Review Article

Soaking as a Processing Method to Improve the Nutritional Value of Soybeans for Livestock

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Abstract

Soybean (*Glycine max* L.) is an important annual leguminous plant that belongs to the pea family Leguminosae. It is considered a global leguminous crop because it can grow in tropical, subtropical and temperate regions of the world. Due to its high nutritional value, soybean is used in human nutrition and is among the extensively used plant source of protein in animal feeds. The crop is valued for its high protein and fat contents. Research revealed that soybean has the highest protein content among all food crops and the second highest in terms of oil content among leguminous plants. Soybean protein contains all the essential amino acids (AA) that are required by animals for proper growth and development. Like all other mammals, humans do not have the ability to synthesize omega 3 and omega 6 fatty acids in the body and must be provided in the food. Soybean contains high amounts of these health-beneficial fatty acids such as linoleic and linolenic which are crucial to maintaining a healthy body and for the prevention of chronic diseases. Nevertheless, some of the anti-nutritional factors (ANFs) present in soybeans limit their optimum utilization in the body of human beings or animals. Some common ANFS identified in soybean include tannins, protease inhibitors, phytates, saponins, and oxalates. All of these contribute to reducing the bioavailability, digestion, and utilization of soybean by animals. This is one of the reasons why animal-fed unprocessed soybeans perform poorly. Several processing methods such as soaking, toasting, boiling, fermentation, germination, pressure cooking, and urea treatment could be employed to reduce the ANFs in soybeans. In an experiment, we investigated the effects of soaking on the ANFs in soybean. The soybean was soaked in clean water for 12, 24, 48, and 72 hrs. We changed the water two times after 24 hrs. After the duration of soaking was achieved, the soybeans were rinsed with clean tap water, dried under the sun for about 8 days, and then ground into flour before being taken to the laboratory for analysis. The proximate composition showed that unsoaked soybean contained 40.28% crude protein (CP), 14.11% fat and 3459.50 kcal/kg DM of metabolizable energy (ME). While soybean soaked for 72 hours had 44.37% CP, 29.55% fat, and 5514.57 kcal/kg DM of ME. Soaking tends to improve the nutritive value of soybean. In addition, soaking reduced the anti-nutritional content of the soybeans. Therefore, farmers could adopt soaking as a means of improving the nutritional value of soybeans for animal production.

Keywords: Soybean; Legumes; Soaking; Anti-nutritional factors; Animal Production

Introduction

Soybean (*Glycine max*) is believed to be one of the oldest crops grown by humans [1]. The botanical name of soybean is *Glycine hispida* or more commonly called *Glycine max* which was the generic name given to it by Carl von Linne [2]. It is widely believed that soybeans originated from Manchuria a province in northern-central China about 5000 years ago. The Chinese emperor in 2838 B.C. was believed to be the first user of the crop [1]. The cultivation of soybeans started in Africa in the late 1800s but the country in which it was first introduced is not known [3]. The countries that are reported to be the major producers of soybeans include the United States of America, China, Nigeria, Brazil, India, Argentina, Uganda, and South Africa [4]. In Nigeria, the major soybean-producing countries in the world are the United States, Brazil, China, Nigeria, India, Argentina, South Africa, and Uganda [4].

The introduction of soybeans to Nigeria

Soybean was believed to be first introduced to Nigeria in 1908, and later around 1928, the crop was successfully distributed to the savannah zones of the country before it finally spread to the northern part of Nigeria [4]. Soybean soon became the major cash crop among the Tiv people of Benue state of Nigeria and thereafter, the state (Benue) became the leading soybean producing area of Nigeria [4,5].

Soybean production in Nigeria

The International Institute of Tropical Agriculture [6] reported that Benue state in Nigeria is the major producer of soybean in the country. This was a result of many years of research which started from the 1960s to the 1980s. During that period, research on soybean was nationally coordinated by scientists in Nigeria. Reports have shown that Nigeria is the largest producer of soybeans for both humans and animals in West and Central Africa [4]. Although, Benue, Kaduna, Kano, Plateau, Oyo, Ondo, Lagos, and the Federal Capital Territory (Figure 1), are the major producers of the crop in Nigeria, however, soybean is also produced in Taraba, Nasarawa, Jigawa, Borno, Kebbi, Sokoto, Kwara, Bauchi and Zamfara [4].

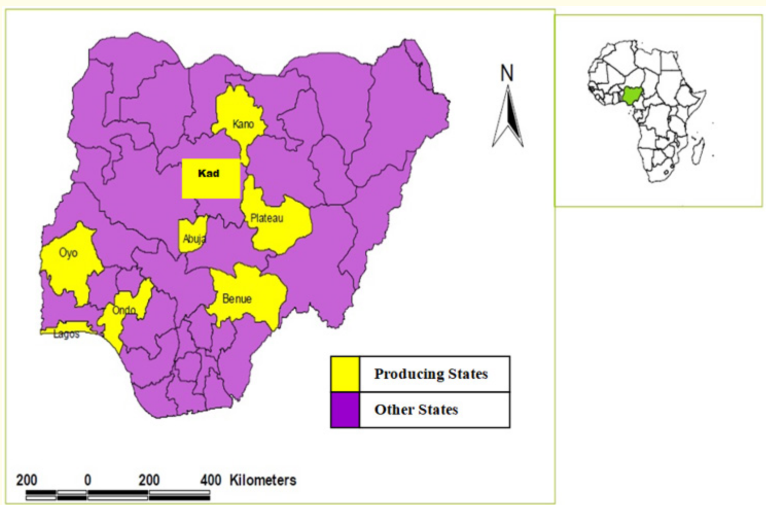

Figure 1: Map of Nigeria showing eight leading soybean producing states.

Source: Adapted from IITA [4].

Importance of soybeans

Soybean is an important annual leguminous crop and is considered a global leguminous crop because it can grow in tropical, subtropical, and temperate regions of the world. It has high nutritional value and is used not only for human consumption but also as a livestock feed ingredient. The crop is valued for its high protein and fat contents [7]. Research revealed that soybean has the highest protein content among all food crops and the second highest in terms of oil content among leguminous plants [5]. Soybean protein contains all the essential amino acids (AA) that are required by animals for proper growth and development. A kilogram of soybean contains about the same protein similar to what is obtained in 2 kilograms of boneless meat or 5 dozen of eggs or 45 cups of cow milk [7]. The protein digestibility corrected amino acid score of soybean is very close to 1, which is the highest rating possible. Therefore, soybean protein has the same rating as protein from animal proteins such as egg white and casein [8]. Compared to animal sources of protein, soybean is widely accepted as a cheaper, readily available source of protein [7]. Like other legumes, soybean contains a high amount of health-beneficial fatty acids such as linoleic and linolenic. These polyunsaturated fatty acids are crucial to maintaining a healthy body and for the prevention of chronic diseases in humans, however, like all other mammals, humans do not have the ability to synthesize omega 3 or omega 6 fatty acids in the body and must be provided in the food.

Soybean is used as a source of protein in the diets of animals due to its high protein content and good nutritional value. Dari [9] reported that for many years, soybeans have been used in the animal feed-producing industries as a significant source of plant proteins. It is accepted globally as a source of high-quality plant protein in animal feed because of its excellent amino acid profile, but methionine is missing in soybeans and must be supplied as a feed additive for production animals. Another good attribute of soybean is that it is available all year round and there is little variation in the nutrient content. With proper processing, soybean will be free from some of the intractable antinutritional factors present in the seed [10]. The production and utilization of soybean will continue as the most preferred source of plant proteins for animal production.

Anti-nutritional factors in soybean

Antinutritional factors can be defined as deleterious compounds found in grain legumes that reduce the bioavailability of nutrients for human beings and monogastric animals [11]. Apart from providing proteins, full-fat soybeans are also rich in ANFs [12]. To reduce ANF in soybeans, generally, processing methods such as heat-treated or cooking with water could be employed, but these methods can be very costly to use, therefore, in our study we used a cheaper processing method (soaking) which could be used by farmers to reduce the levels of ANFs in soybeans before using the product to feed their animals. Monogastric animals and young ruminant animals cannot effectively utilize the nutrients in soybean without processing. Animals fed raw or unprocessed soybeans do not perform well because ANF in soybeans interferes with protein digestion. Examples of some of the ANF in soybeans include protease inhibitors, tannins, phytates, oxalates, saponins, etc [13].

Protease inhibitors

Protease inhibitors represent 6% of the protein present in soybean seeds. They prevent the proper functioning of the enzymes responsible for digesting protein in the diet [14]. Protease inhibitors can block either trypsin or chymotrypsin, reduce the hydrolysis of dietary protein, decrease amino acid absorption and thereby reduce digestibility [15]. Large amounts prevent proper digestion of soy; however, processed soy foods contain only 5% or less of the naturally occurring protease inhibitors [16]. In ruminants, protease inhibitors do not have any effect on digestion because micro-organisms in the rumen degrade the feed unlike monogastric animals [14].

Tannins

Phenolic compounds such as Tannins are mostly water-soluble and have a molecular weight which is greater than 500. Tannins have the ability to precipitate proteins from an aqueous solution and most vascular plants contain Tannin. Lalles [17] reported that Tannins prevent bloating and reduce the degradation of protein in the rumen, thus making protein available for digestion in the hindgut of ruminants [14]. Consequently, feeds with moderate content of tannins may be good sources for enhancing high nitrogen retention [17] growth rate, as well as growth hormone [18]. Feeds with more than 5% condensed tannins can reduce feed intake, and digestibility and cause poor growth in ruminants [15]. Tannins or their oxidized products can form complexes with amino acids, proteins, and enzymes which can adversely affect their digestibility [19]. Ramakrishna., *et al*. [20] have shown that 2 to 3% of dietary condensed tannins formed a protein-tannin complex and prevented protein degradation in the rumen.

Phytates

Legumes such as soybeans contain phytic acid also known as phytates which is a stored form of phosphorus and they prevent the availability and absorption of iron and calcium in animals [20]. Liener [18] reported that phytic acid also reduces the available phosphorus and zinc for animals and decreases the activities of enzymes such as amylase, trypsin, and pepsin. The availability of protein, amino acids, starch, and energy and also reduced by phytates.

Oxalates

Oxalate interferes with the absorption of calcium in animals. Like phytic acid, oxalate like binds minerals such as calcium and magnesium, thereby inhibiting their metabolism [13] however, microbes in the rumen of ruminant animals degrade dietary oxalate into carbon dioxide (CO_2) and formic acid. Ruminants adapted to diets with high oxalate content can tolerate oxalate levels that are lethal to non-adapted animals [21]. In other words, unlike monogastric animals, ruminants can consume considerable amounts of oxalate in their feeds without adverse effects on their performance. This is possible because of the microbial decomposition that takes place in the rumen [16].

Saponins

One unique characteristic of saponins is that they contain a bitter taste and produce a mass of small bubbles (that is that have frothing or foaming properties). Saponins retard the growth rate in monogastric animals because they reduce feed intake [21]. Ruminant animals tend to do well on diets containing saponins because the rumen microbes including bacteria degrade the saponins but Liener [18] observed that saponins inhibit microbial fermentation and synthesis in the rumen. Processing method such as soaking has been shown to reduce the harmful effects of saponins in the diet of animals as feed palatability is increased when the bitter taste is reduced after soaking and draining the water [16].

Methods of alleviating the ANFs in soybean

Increasing the nutritional quality of soybean and other legumes can be accomplished by several processing methods such as soaking, toasting, boiling, salt treatment, fermentation, germination, pressure cooking, cooking, urea treatment, etc [22]. The methods of processing the seeds to eliminate the ANFs have been a major challenge to most farmers [23]. In calves with completely functioning rumen, ANFs and complex proteins are not as detrimental, and thus processing is not as crucial [18]. Several studies have shown that, soaking and sprouting improved the nutritive value of legumes [13,24,25]. Liener [18] showed that the preparation of many indigenous foods from grains involves soaking in water, which is ultimately a household processing method. Similarly, soaking soybean seeds in water could reduce the ANF such as protease inhibitors, phytic acids and certain minerals, and α-galactosides due to their partial or total solubilization and removal with the discarded water [26]. It is against this background that this research work attempt to evaluate the effect of soaking duration as a local processing method on proximate composition and anti-nutritional factors of soybean.

Soaking as a processing method for soybeans

Soaking is a unit operation that involves the immersion of materials (seeds, leaves, and nuts) in water for the purpose of sprouting, fermentation, or softening seeds. Soaking is a common local processing method in Africa that has been reported to influence the properties of legume seeds [15]. It is one of the processing methods used to improve the nutritional value of soybean.

Figure 2: Shows soybean soaked in water during the processing method.

The soybeans were soaked in clean water for 12, 24, 48, and 72 hours. The water was changed twice after every 24 hours. During soaking, seeds absorb water thereby making the feed material become soft, extensible, and flowable, loss of crispness, hardness, or toughness and fermentation of starch components occur simultaneously (Liener, 1985). It also leads to the breakdown of several components into simpler compounds with alterations in texture, flavour, aroma, and taste [18].

Soaking could be one of the processes to remove soluble anti-nutritional factors, which can be eliminated with the discarded solution. However, some metabolic reactions can take place during soaking which will affect some of the constituent compounds [14]. Pele., *et al*. [24] investigated the effect of traditional processing methods on the nutritional and anti-nutritional properties of soybean. The researcher subjected soybean to different processing methods (sun drying and milling, soaking for 24 hours, sun drying and milling, soaking for 12 hours, de-hulling, sun-drying, and milling and sprouting for 120 hours, sun drying and milling). It was shown that the different processing methods significantly improved the nutritional quality and reduced the anti-nutritional properties of soybeans. Also, the study showed that the protein content of soybean was significantly increased while the fat content was significantly reduced due to soaking, de-hulling, and sprouting. Similarly, the phytic acid which hinders minerals absorption was also significantly reduced due to sprouting. And the fat content of soybean which could have a negative effect on rancidity was significantly reduced due to soaking, de-hulling, and sprouting [24].

Effect of soaking on the chemical composition of soybean

The results of the soaking of soybean in water (Table 1) revealed that soaking significantly ($P < 0.05$) reduced the levels of some ANFs. Soybeans not soaked in the water had 4.39, 7.09, 0.42, 1.04, and 2.46 mg/100ml levels of phytates, protease inhibitors, tannins, oxalates, and saponins, respectively. Soaking for 12 hours reduced the levels of phytates from (4.39 to 2.21mg/100ml), protease inhibitors (7.09 to 6.03mg/100ml), tannins (0.42 to 0.36 mg/100ml), oxalates (1.04 to 1.00 mg/100ml) and saponins (2.46 to 1.06 mg/100ml), respectively.

Figure 3: Shows how the soybeans were after which the water was drained. The soybeans were dried for about 8 hours because of the prevailing weather condition.

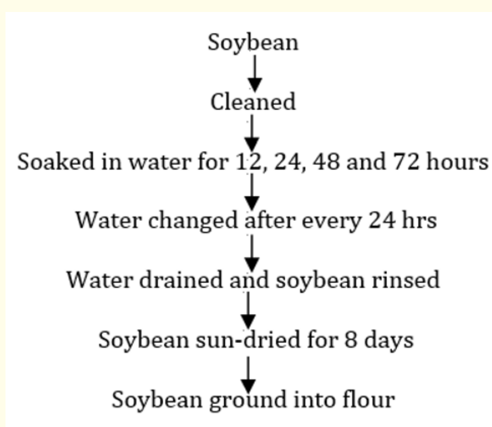

Figure 4: Shows the flowchart of soaking as a processing method for soybean.
Source: Adapted from Gadzama *et al*. [25].

Increasing the soaking duration resulted in an increased reduction in the levels of all the ANFs studied. Soaking for 72 hours had the highest level of the percent reduction in ANFs (90.89, 46.54, 57.14. 19.23, and 60.16 for phytates, protease inhibitors, tannins, oxalates, and saponins, respectively).

	Duration of Soaking (hours)				
Parameters (mg/100ml)	**0**	**12**	**24**	**48**	**72**
Phytates	4.39	2.21	1.29	1.75	0.40
Protease inhibitors	7.09	6.03	5.72	4.91	3.79
Tannins	0.42	0.36	0.28	0.24	0.18
Oxalates	1.04	1.00	0.96	0.94	0.84
Saponins	2.46	1.06	1.04	1.02	0.98
% Reduction in ANFs					
Phytates	-	49.66	70.62	60.14	90.89
Protease Inhibitors	-	14.95	19.32	30.75	46.54
Tannins	-	14.29	33.33	42.86	57.14
Oxalates	-	3.85	7.69	9.62	19.23
Saponins	-	56.91	57.72	58.54	60.16
DM = Dry Matter; ANFs = Anti-Nutritional Factors					

Table 1: Anti-Nutritional Factors in Unsoaked and Soaked Soybean on DM basis.

The chemical composition of soybeans at the different duration of soaking was comparable to values earlier reported by Pele., *et al*. [24]. The high DM content observed in all the samples could be attributed to adequate drying of the soybean seeds after soaking which reduced the moisture content. Moisture content is very important in food storage and processing. Moisture affects the shelf life and nutrition of food products. Dari [9] reported that soy flour should have a low moisture content to avoid contamination by mycotoxins and fungus. Aruah., *et al*. [27] stated that the moisture content of any food is an index of its water activity and is used as a measure of stability and susceptibility to microbial contamination, indicating that soybeans can be processed into flour after soaking and drying and the soy flour could be kept in a polythene bag for some time without microbial spoilage and deterioration in quality.

There was an increase in crude protein content with increasing duration of soaking which could be attributed to changes that occur in complex biochemical during hydration which led to the breakdown of protein constituents by enzymes into simple compounds that are used to make new compounds [12]. Similar results were reported by Pele., *et al*. [24] for an increase in crude protein content which was attributed to sprouting which increased the bioavailability of protein content in the soybeans. The reduction in protein content in soybeans soaked for 24 hours compared with soybeans soaked for 72 hours could be attributed to the leaching of amino acids, which are the building blocks of proteins as reported by Maidala., *et al*. [12]. The results of this study showed that soaking did not reduce the crude protein content of soybeans. The increased fat content observed in this study was attributed to the synthesis of fatty acids as a result of soaking the soybeans in water. This supports the report of Hanssen [28] who observed an increase in fat content after 12 hours of soaking soybeans. But is different from the report of Sharma., *et al*. [29] who observed a decrease in fat content of sprouted soybeans which was attributed to the utilization of fat as an energy source during the sprouting period or the hydrolysis of fat to glycerol and fatty acids in the presence of lipolytic enzymes. However, soaking decreased the crude fibre, ash, and carbohydrate contents of the soybeans. The decrease in carbohydrates might be due to an increase in alpha-amylase activity.

The alpha-amylase breaks down complex carbohydrates into simple and more absorbable sugars, which are utilized by the seeds during the early stages of soaking, thereby resulting in a loss in dry matter content [30]. Legumes have been reported to be good sources of ash [27]. Ash content refers to the inorganic substance which translates into high mineral contents [29]. Soaking reduced the ash content of the soybeans which could be a result of biochemical reactions. As the content of crude fibre and nitrogen-free extract reduced from the soybean due to the leaching of soluble carbohydrates (oligosaccharides), the other components such as crude protein and fat increased, thus improving the nutritional value of the soymilk. Soybean processing treatments like soaking were reported to substantially reduce the content of fermentable, soluble carbohydrates [12]. The higher fat contents in soybeans soaked for 48 and 72 hours might be responsible for the higher values of metabolizable energy (5631.61 and 5514.57 kcal/kg DM, respectively) obtained in the study.

Conclusion

Soaking of soybeans in water for 12, 24, 48 and 72 hrs generally improved the chemical composition and reduced the levels of ANFs, but soybeans soaked for 72 hrs had the best percent reduction in ANFs. Therefore, soaking as a processing method could be used to remove soluble anti-nutritional factors from soybeans thereby improving their feeding value for animals.

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