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Effect of Processing Methods on Some Antinutritional Factors in Legume Seeds for Poultry Feeding

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Abstract: Removal of undesirable components is essential to improve the nutritional quality of legumes and effectively utilize their full potential as poultry feed ingredient. It is widely accepted that simple and inexpensive processing techniques are effective methods of achieving desirable changes in the composition of seeds. Different authors have reported that soaking, cooking, toasting, autoclaving, microwave cooking, pressure cooking, extrusion cooking, germination and chemical treatment improve the quality of legumes because of the removal or inactivation of some anti-nutritional factors. In many instances, usage of only one method may not effect the desired removal of anti-nutritional substances and a combination of two or more methods may be required.

Key words: Processing, effect, antinutritional factors, legume seeds

INTRODUCTION

Legumes represent a major source of nutrients, including valuable but incompletely balance protein, particularly in vegetarians' diet (Ghadge *et al.*, 2008a). The nutritive value of legumes depends upon the processing methods, presence or absence of antinutritional or toxic factors and possible interaction of nutrient with other food components (Ghadge *et al.*, 2008b). To improve the nutritional quality and to provide effective utilization of legume grains for poultry, it is essential that anti-nutritional factors be removed or reduced. So, it is necessary to establish processing technique(s) to insure its optimal utilization. In order to inactivate or reduce anti-nutrients, various conventional, simple processing methods have been used in legume seeds (Barbour *et al.*, 2001; Farran *et al.*, 2001).

Heat treatment: Heat processing is widely accepted as an effective means of inactivating the thermo-labile antinutritional factors of legume grains. The nutritive quality of most tropical legume grains, particularly cowpea, soybean, pigeon pea, lima bean and winged beans is notably improved by heat treatment. Heat treatment is a usual process before legumes are used in the human diet. This improves protein quality by inactivating anti-physiological factors, particularly trypsin inhibitor and haemagglutinins and by unfolding the protein structure, thus making them more susceptible to attack by digestive enzymes (Sathe *et al.*, 1984). Osborne and Mendel (1917) noted that dry heat was less effective than cooking (moist heat) for the improvement of growth promoting action in soybeans.

Other authors (Babar *et al.*, 1988; Bressani and Sosa, 1990; Carlini and Udedibie, 1997) have also reported the superiority of moist heat over dry heat as a method for processing jackbean seeds. Moist heating is often more effective than dry heating and the degree of inactivation is governed by temperature, duration of heating and particle size (D' Mello, 1982).

Cooking (boiling): Cooking generally inactivates heat-sensitive anti-nutritive factors such as trypsin and chymotrypsin inhibitors and volatile compounds. The cooking water may be discarded, but some other soluble compounds could be removed. Bressani and Elias (1980) observed that about 30-40% of polyphenols can be removed from *Phaseolus vulgaris* by cooking and discarding the cooking water solution. Cooking for 60 minutes at 100°C was sufficient to inactivate over 90% of the trypsin inhibitor activity in *Phaseolus vulgaris* (Trugo *et al.*, 1990). Udedibie and Nwaiwu (1988) subjected jackbeans to four different cooking periods of 30, 60, 90 and 120 min, taking the period of cooking as starting from boiling. This was followed by drying in the oven at 60-70°C and grinding. Phytochemical analysis of raw and cooked samples showed that cooking for 60 min was enough for the elimination of most of the thermo-labile anti-nutritional factors in the jackbean such as saponins, cyanogenic glycosides, terpenoids and alkaloids which were detected in raw jackbeans. Carlini and Udedibie (1997) reported that it took 2 h of boiling to completely eliminate trypsin inhibitor activity in jackbean and 3 h of boiling to render the legume lectin-free.

Two-stage cooking: Two-stage cooking, the method used in some villages in Nigeria to cook some poisonous local foodstuffs, has also been applied to jackbean. This process involves cooking the beans for about an hour, then discarding the initial water used in cooking and cooking again for about 40 min with fresh water (Udedibie *et al.*, 1996).

Autoclaving: Autoclaving entails cooking under pressure. The time of cooking is shortened by this method. When jackbeans were autoclaved for 30 minutes at 125°C and 15 lb pressure, thermo-labile inhibitory substances such as cyanogenic glycosides, saponins, terpenoids and alkaloids could not be detected after autoclaving (Udedibie and Nwaiwu, 1988). The nutritive value of many legumes is enhanced by autoclaving and this effect is probably related to the destruction of haemagglutinins and other growth inhibitory factors. Preliminary soaking prior to autoclaving is required for complete elimination of the toxicity of kidney bean (Jaffe, 1949) and field beans (Phadke and Sohoni, 1962). Kakade and Evans (1965) found that autoclaving for 5 min was sufficient to eliminate the toxicity of finely ground navy bean meal. Kessler *et al.* (1990) stated that there was little nutritional advantage in autoclaving for more than half an hour. They reported that autoclaving of jackbeans was a satisfactory technique for ensuring survival of birds receiving jackbean diets, confirming the findings of Jayne-Williams (1973) and D'Mello *et al.* (1985). The absence of lesions on the small intestine cells of broilers fed autoclaved jackbean suggest the elimination of the lectins during the autoclaving of the jackbeans. Nevertheless, autoclaving alone was insufficient to allow jackbean to be used in conventional chick diets since even the autoclaved jackbeans produced severe growth retarding effects due to the presence of heat-stable toxic factors in jackbean (Kessler *et al.*, 1990). Dixon *et al.* (1983) reported that autoclaved *Canavalia ensiformis* seeds included at levels of 100 and 150 g/kg in chick diets led to growth rate increases of 58-76% in comparison with raw seeds.

Pressure cooking: Carlini and Udedibie (1997) stated that since it is a common practice to use a pressure cooker to cook most legume grains to save time and cost, they decided to determine how long it would take the pressure cooker to completely inactivate the conca-*navalin* A and trypsin inhibitors in *Canavalia ensiformis*. The beans were subjected to four different pressure cooking times: 15, 30, 45 and 60 min. The jackbeans so cooked were dried, milled, extracted and analyzed for haemagglutinating and anti-tryptic activities. It took 30 min of pressure cooking to completely inactivate the trypsin inhibitor in *Canavalia ensiformis* while conca-*navalin* A required 45 min for complete inactivation, establishing the fact that conca-*navalin* A

was more resistant to heat treatment than trypsin inhibitors. Poultry have been reported to show some negative response to 200-300 g/kg dietary inclusion of *Canavalia ensiformis* that had been pressure-cooked for 30 min (Jayne-Williams, 1973; D'Mello *et al.*, 1985; Udedibie and Nwaiwu, 1988; Udedibie and Madubuike, 1988). Although pressure cooking of the *Canavalia* seeds can be useful for some domestic purposes, its application in large-scale commercial operation cannot be recommended with enthusiasm in view of difficulties relating to the equipment required (Carlini and Udedibie, 1997).

Microwave treatment: Kadam *et al.* (1987) in their experiment with winged bean (*Psophocarpus tetragonolobus*) meal, adjusted the moisture content in winged bean meal to 15% and allowed the meal to stand overnight at room temperature. The meal was then heated for 10 min in a Philips (Model 4915) microwave oven adjusted to 50% power input. These workers reported that trypsin inhibitor activity and haemagglutinating activity in winged bean meal were not affected by microwave treatment. D'Mello and Walker (1991) stated that microwave cooking of jackbeans was only marginally less effective than autoclaving of KHCO₃-extracted jackbeans. This contrasts with the work of Kadam *et al.* (1987) who demonstrated marked superiority of autoclaving procedures over microwave treatment of winged beans. It is recognized that further research is required to examine the effects of sample size and heating times in order to adequately evaluate the efficacy of microwave treatment in the detoxification of jackbeans.

Extrusion cooking: Partial detoxification of jackbean seeds by extrusion cooking has been reported by several workers (Aguirre-Montana, 1988; Bressani and Sosa, 1990; Leon *et al.*, 1991). Although Melcion *et al.* (1991) claimed complete inactivation of haemagglutinins in jackbean through extrusion cooking, a feeding trial with the product indicated only partial detoxification since it still depressed growth of the experimental cockerels. It thus showed that growth retarding effects of haemagglutinins were still present in the jackbean so treated. Pinto *et al.* (1997) reported that extrusion cooking of soybean even after malting could not completely inactivate trypsin inhibitors in the seed. Any heat treatment that cannot completely eliminate trypsin inhibitors from a seed will obviously have little effect on lectins (Carlini and Udedibie, 1997). The nutritive value of extruded jackbeans is similar to that of the field beans (Lacassague *et al.*, 1988).

Toasting: The improvement in the nutritive quality of jackbeans through toasting was first reported by Borchers and Ackerson (1950). However, toasting alone could improve its nutritive value for broiler chickens only

to the extent of up to 100/kg dietary inclusion (Udedibie *et al.*, 1994). Studies by Esonu *et al.* (1998) have demonstrated that toasting alone as a method of processing jackbean seeds did not appreciably reduce the level of toxic factors in jackbeans.

Soaking: Soaking could be one of the processes to remove soluble antinutritional factors, which can be eliminated with the discarded soaking solution. However, some metabolic reactions can take place during soaking which will affect some of the constituent compounds (Vidal-Valverde *et al.*, 1992). The anti-nutritive constituents of jackbean which have been reported to be hydrosoluble are canavanine and canaline (Liener, 1980). Desphande and Cheryan (1983) reported retention of 98-99% of trypsin inhibitor activity in many cultivars of *Phaseolus vulgaris* after the seeds were soaked in water for 18 h. Liu and Markakis (1987) also observed that soaking of soybeans in water at 22°C for 24 h had no effect on the trypsin inhibitor activity. Dhurandhar and Chang (1990) soaked navy and red kidney beans for 16 h in water at ambient temperature and both showed insignificant decreases in trypsin inhibitor activity. Trugo *et al.* (1990) also did not find any loss of activity when black beans were soaked in water for 16 h. However, soaking of lentil seeds for 24 h in distilled water resulted in a 58-66% decrease in trypsin inhibitor activity (Batra *et al.*, 1986).

Germination (sprouting): The process of germination does not require intensive energy output and also yields natural products. Germination has been documented to be an effective treatment to remove some anti-nutritional factors in legumes by mobilizing secondary metabolic compounds which are thought to function as reserve nutrients. According to Esonu *et al.* (1998), sprouting initiates three main types of chemical changes in the seed which include the breakdown of certain materials, transport of materials from one part of the seed to another especially from the endosperm to the embryo or from the cotyledons to the growing parts and the synthesis of new materials from the breakdown product formed. During seed germination, storage proteins are hydrolyzed and the amino acids are transported into the growing seedling axis. Phytic acid serves as an important reserve of phosphate generated by the action of phytase during seed germination for the developing seedling. Reddy *et al.* (1978) noted that phytic acid was hydrolyzed during germination resulting in an increase in available inorganic phosphorus. Germination can lower the phytate content in legume seeds depending upon the type of bean and germinating conditions. Germination of soybeans improves the nutritional value (Mattingly and Bird, 1945) but in field beans, no such effect was observed (Phadke and Sohonie, 1962). Germination of rapeseed is accompanied by an

increase in phytase level to effect a decrease in phytic acid, which is an important antinutritional factor present in many seeds. As the seedling grows, phytin disappears from the tissues and this has been attributed to the increased phytase activity. Belavady and Banerjee (1953) observed that in lentils, 53% phytic acid hydrolyzed after 5 days of germination. Verma and Mehta (1988) have found that on sprouting, the phytic-phosphorus value for rice bean (*Vigna umbellata*) and mung bean (*Phaseolus aureus*) decreased by 11.3% and 9.8% respectively, as compared with the whole ungerminated bean. Reduction in the levels of phytic acid increased the availability of the minerals in the digestive tract of animals as the chelating capacity of phytic acid is reduced (Khan *et al.*, 1991; Sharma *et al.*, 1996).

The process of germination is believed to facilitate the inactivation process of concalectin A in seeds since haemagglutinating activity has been reported to decrease with germination (Liener, 1986). Studies by Esonu *et al.* (1998) showed that sprouting reduced haemagglutinating activity in jackbean by 49%. The reduction in canavanine concentrations in the germinating seed of jack bean has been widely reported (Johnstone, 1956; Bell, 1960; Ho and Shen, 1966; Rosenthal, 1970; Nakatsu *et al.*, 1996). In contrast however, D'Mello *et al.* (1988) questioned the method of sprouting jackbean seeds as a strategy for reducing the concentration of canavanine because canaline is the most likely product of canavanine metabolism in the germinating seed. Esonu (1996) showed that jackbean seeds still exhibit strong toxic effects in chicks even after sprouting prior to heating in the oven.

Chemical treatment: Various chemical treatments have been employed in attempt to improve the nutritional value of legumes. Ologhobo *et al.* (1993) reported that the extraction of jackbean flour with different solvents yielded fractions of varying toxicities, based on the solubility or otherwise of the toxic principles in the extracting medium. They reported higher concentrations of antinutritional factors in the base-soluble fraction than in the other fractions, indicating a greater extractability of anti-nutritional factors by alkali treatment than by acid, ether or alcohol. D'Mello and Walker (1991) achieved considerable success by using the alkali, potassium bicarbonate to detoxify jackbeans. The relative ease with which canavanine was extracted from the whole beans indicated the complete solubilisation of canavanine in the alkali. A substantial amount of trypsin inhibitors have been reported to leach out of Great Northern beans by soaking in acidic or alkaline solutions (Eicher and Satterlee, 1988). Fernandez *et al.* (1993) observed that soaking faba beans in 0.07% sodium bicarbonate solution was more effective in decreasing the trypsin inhibitor activity than soaking it in 0.1% citric acid

solution, probably due to the stability of the inhibitor in acidic pH.

Urea treatment: Urea is a very strong protein-denaturing agent and can achieve this by competing for hydrogen bonds with the peptide backbone, thereby breaking up the secondary structure of these native proteins and disrupting their biologically active structures (Rawn-David, 1983).

Urea solution treatment: Raw jackbean seeds were soaked in 3% solution of urea for 6 days at room temperature in plastic containers. During this period, strong ammonia gas odour was released from the solution. At the end of the period, the beans were rinsed with tap water and then cooked for one hour, dried in the oven at 80°C and then ground (Udedibie and Nkwocha, 1990). Feeding trials with the resultant jackbean meal involving young broiler chicks demonstrated that jackbeans so processed could be tolerated by broiler chicks at up to 25% inclusion level in the diet (Udedibie and Nkwocha, 1990). Soaking of the jackbean in urea solution prior to cooking has proved to be a very viable means of adequately improving its nutritive quality. This treatment however, is expensive and tedious but it has demonstrated that some biochemical changes induced with urea or any strong denaturing agents are necessary against the heat-stable anti-nutritional substances in the jack beans before heating, for sufficient dietary inclusions.

Dry urea treatment: The procedure for dry urea treatment of jackbean as outlined by Udedibie *et al.* (1994) is as follows; raw jackbeans were grinded using a 2 mm Screen Wiley mill. A batch of the jackbean meal was thoroughly mixed with 2.5% of its weight of urea which had already been ground into powder. The mixture was then stored in a sack for a week. Crude protein content of the meals was determined every other day as a way of monitoring the urease activity of the jackbean. At the end of the storage period jackbean meal so treated were subjected to High Temperature Short Time (HTST) heat treatment. This involved toasting in a pan under fire for 20-30 min or heating in the oven at 100°C until the meals turned from white to light yellow in colour and crispy.

The processed jackbean meals were then included at 10 and 20% dietary levels, respectively and fed to finisher broilers for 5 weeks. Broilers could tolerate the dry urea treated jackbean meal at up to 20% in their diets (Udedibie *et al.*, 1994).

Conclusion: It is necessary to develop improved methods for detoxifying legume seeds so that their potential for use in poultry diets is completely achieved. Processing methods for use in commercial feed

production must be simple, economical, feasible and inexpensive. In many instances, usage of only one method may not effect the desired removal of antinutritional substances and a combination of two or more methods may be required.

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