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Research Article

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Physicochemical and functional properties of starches from Indian Jack bean (*Canavalia ensiformis*), an underutilized wild food legume

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ABSTRACT

The objective of the present study was to evaluate jack bean seeds with the aim of quantifying physiochemical and functional properties information that might serve as a guide to exploit its potential and benefits for human and animal nutrition. The proximate compositions (g100 g^{-1} flour) were determined as moisture content (5.73 ± 0.03), ash (2.11 ± 0.20), crude fibre (6.13 ± 0.12), crude carbohydrate (41.26 ± 0.01), crude fat (3.17 ± 0.1 0), crude protein (24.32 ± 0.11) and gross energy is (1261.15 ± 0.20 kJ 100 g^{-1}). The functional properties of amylose content, swelling power, solubility, oil absorption capacity and water absorption capacity of starches are 33.24 ± 0.15 %, 17.34 ± 0.01 g/g, 24.56 ± 0.02%, 85.76 ± 0.03%, 98. 87 ± 0.10% respectively. Foaming capacity, foaming stability and emulsifying capacity, emulsion stability were investigated as 18.16 ± 1.0, 8.21 ± 0.01 and 55.14 ± 0.05, 15.17 ± 0.11% respectively. The present study may provide a guideline for the use of Jack bean seed flour are good functional foods for nutrition, food formulation and utilization.

Key words: Physical composition, proximate composition, functional properties, starch isolate, Jack bean.

INTRODUCTION

Legumes are good sources of cheap and widely available proteins for human consumption. They are staple foods for many people in different parts of the world [1]. Legume seeds have an average of twice as much protein as cereals and the nutritive value of the proteins are usually high [2]. Legume seeds are of prime importance in human and animal nutrition due to their high protein content (20 - 50%) [3] and have historically been utilized mainly as the whole seeds [4]. Recently, they are now being fractionated into their main constituents which are starch and protein. Starch, the principal carbohydrate constituent of majority of plant materials, merits a detailed investigation to understand better its biochemical and functional characteristics as well as variations [5]. Starch is considered of commercial importance due to its high industrial demand as an ingredient for a variety of processed foods [6]. The growing demand for starches for the modern food industry has created interest for new sources of the polysaccharides [7]. Applications of starch in food systems are primarily governed by gelatinization, pasting, solubility, swelling and digestibility properties.

Jack bean (*Canavalia ensiformis*) is one of the under exploited tropical dry beans. It is, however, fairly widely distributed, being cultivated in Africa, Asia, the West Indies, Latin America and India. Raw Canavalia seeds contain about 300 g kg^{-1} protein and 600 g kg^{-1} carbohydrates [8] hence; they have great potential as dietary protein feedstuff for monogastrics and poultry [9-14]. These antinutritional factors are solubilized nitrogenous compounds which require deactivation by moist heat treatment and/or extraction prior to use as feedstuffs [15-20].The mature seeds are consumed by the Indian tribal sects, Kurumba, Malayali, Erula and other Dravidian groups, after cooking [21]. In western countries this legume is used as a cover crop and the roasted seeds are ground to prepare coffee-like drink [22]. The aim of the present study was to evaluate physicochemical and functional Properties of starches from Indian Jack bean.

EXPERIMENTAL SECTION

Sample collection

Natural strands of mature pods of *Canavalia ensiformis* (jack bean) were purchased from local grocery markets of Madurai, Tamil Nadu, India.

Determination of Physiochemical properties

The jack bean seed mass, m (g) was recorded by using an experimental balance (Sartorius Basic, India) with an accuracy of ± 0.001 g. Geometrical dimensions length, width and breadth were measured with a digital vernier caliper (Mitutoyo, Japan) with an accuracy of ± 0.01mm.

Moisture was assessed on subjecting the seed flour to 100°C in an incubator to attain constant weight and the difference in initial and final weight of floor was expressed as percentage moisture. Total nitrogen and the crude protein content (N×6.25) were determined by micro-kjeldahl method [23].Crude lipid, crude fiber and ash contents were detected on employing AOAC methods [24].Crude carbohydrate was calculated as outline by [25]:

Total crude carbohydrates (%) = 100-(Crude protein + Crude lipid + Ash).

Gross energy was calculated based on formula given in [26]: Gross energy (kJ/100g DM) = (Crude protein× 16.7) + (Crude lipid×37.7) + (Crude carbohydrates).

Determination of Functional properties

Amylose content

Amylose content of the legume starches was deter-mined by following the method of [27]. A starch sample (20 mg) was taken and 10 ml of 0.5 N KOH was added to it. The suspension was thoroughly mixed. The dispersed sample was transferred to a 100 ml volumetric flask and diluted to the mark with distilled water. An aliquot of test starch solution (10 ml) was pipetted in to a 50 ml volumetric flask and 5 ml of 0.1 N HCl was added followed by the 0.5 ml of iodine reagent. The volume was diluted to 50 ml and the absorbance was measured at 625 nm. The measurement of the amylose was determined from a standard curve developed using amylose and amylopectin blends.

Swelling power and Solubility

Swelling power and solubility were determined using the method of [28]. A 1% aqueous suspension of starch (100ml) was heated in a water bath at 90°C for 1 hour with constant stirring. The suspension was cooled for half an hour at 30° C. Samples were then poured into pre-weighed centrifuge tubes, centrifuged at 30000rpm for 10 min and weight of sediments was determined. Solubility was measured by pouring into evaporating dishes and evaporated at 110° C for 12 hour and weight of dry solids was determined.

$$\text{Starch solubility (\%)} = \frac{\text{wt. of suspension (dry)} \times 100}{\text{Wt. of dry starch}}$$

$$\text{Swelling power (wt/wt)} = \frac{\text{wt. of swollen sediment}}{\text{Wt. of soluble starch}}$$

Oil and Water absorption capacities

One gram of sample was mixed with 10ml refined soybean oil or distilled water in a weighed 20mL centrifuge tube. The slurry was agitated on a Vortex mixer for 2 minutes, allowed to stand at 28° C for 30 minutes and then centrifuged at 500×g for 30 minutes. The clear supernatant was decanted and discarded. The adhering drops of oil or water were removed and the tube was weighed. The weight of oil or water absorbed by1g of flour of protein was calculated and expressed as oil or water absorption capacity [29, 30].

Foaming Capacity

The method described by [31], modified by [32] was used to determine the foam capacity and foam stability. Two grams of flour sample was added to 50mL distilled water at 30 ± 20 C in a 100mL measuring cylinder. The suspension was mixed and properly shaken to foam and the volume of the foam after 30 seconds was recorded.

Foaming Stability

The foam capacity was expressed as a percentage increase in volume. The foam volume was recorded 2 hours after whipping to determine the foam stability as a percentage of the initial foam volume.

Emulsion Capacity
Emulsion capacity was determined using the procedure described by [33]. Flour sample of 0.5g was made into slurry in 5mL of distilled water in an Erlenmeyer flask stirring at 1,000 rpm for 15 minutes with a magnetic stirrer. 5mL of refined soybean oil was added over a period of 5 minutes, stirring at 1,000rpm, stirring as continued for an extra minute. The system was transferred into a centrifuge tube treated in a water bath maintained at 85°C for 15 minutes with occasional stirring and then cooled for 15 minutes in a water bath maintained at 25°C. The tube was finally centrifuged at 3,500 rpm until the height of the oil (separated from emulsion) was constant. Results were expressed as a percentage of the emulsion after separating the upper layer from emulsion.

Emulsion stability
Emulsion stability was determined by following the method described by [34]. Flour sample of 0.5g was blended in a Beltone blender with 50mL of distilled water for 30 seconds at high speed. Oil was added to 50mL proportion with continued blending. The addition of the oil was stopped when the nature of the emulsion changes, as marked by decreased homogeneity. The emulsion prepared was allowed to stand on a graduated cylinder for 24 hours, after which the emulsion capacity was calculated to give the emulsion stability expressed as a percentage, it was calculated as the ratio of the weight of the emulsified layer to the total height of mixture.

RESULTS AND DISCUSSION

Physiochemical properties of Jack bean
The profiles of physical characteristics and proximate composition in raw seed samples are showed in Table 1. Significant variation in the levels of proximate composition was observed. The content of moisture, ash, crude fibre, crude carbohydrate, crude fat, crude protein and gross energy are, 5.73 ± 0.03 %; 2.11 ± 0.20 g $100g^{-1}$; 6.13 ± 0.12 g $100g^{-1}$; 41.26 ± 0.01 g $100g^{-1}$; 3.17 ± 0.10 g $100g^{-1}$; 24.32 ± 0.11 g $100g^{-1}$; 24.32 ± 0.11 kJ 100 g^{-1}, respectively.

Functional properties of Jack bean
The functional properties of seed flour of jack been are showed in Table 2. Legume starches have been characterized by a high amylose content of 24 – 65% [35]. Starch paste behavior in aqueous system depend on the physical and chemical characteristics of the starch granules, such as mean granule size, granule size distribution, amylose/amylopectin ratio and mineral content [36]. The amylose content of the starch varies with the botanical source of the starch and is affected by the climatic conditions and soil type during growth [37]. The amylose content of the Indian wild jack bean is 33.24 ± 0.14%.

Swelling power and solubility provide evidence of the strength of interaction between starch chains within the amorphous and crystalline domains [38]. The swelling power of starch has been reported to depend on water holding capacity of starch molecules by hydrogen bonding [39]. Hydrogen bonds stabilizing the structure of the double helices in crystallites are broken during gelatinization and are replaced by the hydrogen bonds with water, and swelling is regulated by the crystallinity of the starch [40]. Swelling power and solubility of jack bean were found to be 17.34 ± 0.01g g^{-1} and 85.76 ± 0.03% respectively. The swelling power of jack bean starches may be attributed to the presence of a large number of crystallites formed by the association between long amylopectin chains.

The water and oil absorption capacities are essential functional properties of protein which may be defined as the amount of water or oil retained by a known weight of flour under specific conditions. The water absorption capacity depends on capillary, pore size and the charges on the protein molecules. This is due to strong correlation of extent of protein hydration with polar constituents along with the hydrophilic interaction through hydrogen bonding. The higher protein content in the flour might be responsible for high hydrogen bonding and high electrostatic repulsion [41]. The oil absorption capacity is also due to enhanced hydrophobic character of proteins in the flours. WAI of legume starches is inversely related to solubility and directly related to swelling [42]. The WAI is a useful indication of whether flours or isolates can be incorporated into aqueous food formulations especially those involving dough handling where an increase in unit yield is desirable [43]. Water and oil absorption capacities of jack bean were found to be 98.87 ± 0.10 and 85.76 ± 0.03% respectively. It also indicates the gelling capacity of the starch and also very important in the texture of food systems. Jack bean starch can contribute greatly to the textural properties of many foods and in industries as a thickener, gelling agent and bulking agent.

Foaming properties are much important in the maintenance of the texture and structure of different food products (ice creams and bakery products) during and after processing. The foam stability of the flour depends on the presence of the flexible protein molecules which may decrease the surface tension of water [44]. The results revealed that foaming capacity and foaming stability of jack bean seed flour were found to be 18.16 ± 1.00% and 8.21 ± 0.01% respectively. The low foam ability of lotus rhizome flour indicates the presence of highly ordered globular protein molecules which increase the surface tension. In food foams, foaming performance depends on the

ability of the continuous phase to include air (foam capacity) and also retain it for specific period of time (foam stability) [45]. [46] Also reported that ability of protein to reduce surface tension upon adsorption affects foam formation. According to [47], ability to form stable foam depends on sufficient intermolecular (protein-protein) interaction and thus degree of cohesion.

Emulsion capacity determines the maximum amount of oil that can be emulsified by protein dispersion. On the other hand, emulsion stability determines the ability of an emulsion with a specific composition to remain unchanged. Jack bean seed powder exhibited good emulsion properties (emulsion capacity of 55.14 ± 0.05% and emulsion stability of 15.17 ± 0.11%). Emulsion stability is important in food emulsions as it indicates the capacity of emulsion droplets to remain dispersed without separation by creaming, coalescing and flocculation [46]. Unfolding of proteins at oil and water interfaces plays a significant role in formation and stability of emulsions. Other factors such as adsorption kinetics, interfacial load, decrease of interfacial tension, rheology of the interfacial film and its surface hydrophobicity also affect emulsion properties [48]. The result showing jack bean could be attributed to protein denaturation during isolation.

Table-1: Physical characteristics and proximate composition of seeds of jack bean

Physical Composition		Proximate Composition	
Seed weight (g seed $^{-1}$)	1.325	Moisture content (%)	5.73 ± 0.03
Cotyledon weight (g seed $^{-1}$)	1.11	Ash content (g 100g^{-1})	2.11 ± 0.20
Seed coat weight (g seed $^{-1}$)	0.18	Crude fibre (g 100g^{-1})	6.13 ± 0.12
Seed length (mm seed $^{-1}$)	15.31	Crude carbohydrate (g 100g^{-1})	41.26 ± 0.01
Seed width (mm seed $^{-1}$)	12.17	Crude fat (g 100g^{-1})	3.17 ± 0.10
Seed thickness (mm seed $^{-1}$)	9.16	Crude protein (g 100g^{-1})	24.32 ± 0.11
Hilum length(mm seed $^{-1}$)	9.21	Gross energy (kJ 100 g^{-1})	1261.15± 0.20

All the values are ±SD

Table -2: Functional properties of starches separated from Jack bean

Parameter	Jack bean
Amylose content (%)	33.24± 0.15
Swelling power(g/g)	17.34± 0.01
Solubility (%)	24.56± 0.02
Oil Absorption Capacity (%)	85.76± 0.03
Water Absorption Capacity (%)	98.87± 0.10
Foam capacity (%)	18.16± 1.00
Foam stability (%)	8.21± 0.01
Emulsion capacity (%)	55.14± 0.05
Emulsion stability (%)	15.17± 0.11

All the values are ±SD

CONCLUSION

In conclusion, the physico-chemical, and functional properties obtained indicate that jack bean can be used as alternative binders owing to its appreciably values of swelling power and solubility. However, the starch isolate exhibited good oil and water absorption, foam and emulsion properties. From the findings, jack bean starch could be used in food systems as a functional ingredient after modification through physical, chemical, or enzymatic methods to improve functional properties. Overall, jack bean starch isolate has good nutritional quality and used as functional foods.

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