Functional Properties of Processed Pinto Bean (*Phaseolus vulgaris* L.) Grown in Plateau State, Nigeria

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Abstract

It is well documented that processing method influences the chemical composition and utilization of plant foods. For this purpose, the effect of different processing methods (boiled, cooked, roasted, sprouted and fermented) was investigated on the functional properties of pinto bean (*Phaseolus vulgaris* L.) flour. Functional properties (water, oil, oil emulsion and foaming capacities: WAC, OAC, OEC, FC; foaming and oil emulsion stabilities: FS, OES; least gelation concentration: LGC; bulk density: BD; protein solubility: PS) of raw and processed pinto bean flour were all determined using standard analytical techniques. The results showed that OEC, OES, LGC and BD were enhanced by different processing methods while WAC and OAC were reduced by roasting method. Processing significantly ($p \leq 0.05$) affected the content of some functional parameters in pinto bean flour. Boiling, sprouting and fermenting increased WAC and OAC contents by 34.6, 28.8, 21.2% and 33.0, 24.2, 36.3%, respectively while cooking, roasting and sprouting reduced FS by respective 3.9, 32.4 and 13.6%. The protein solubility studies of the raw and processed sample flour were found to have minimum solubility at pH range of 4.0 to 5.2 which correspond to isoelectric points where protein isolates might be recovered from the samples. Generally, all the functional parameters determined in this study were good thereby making raw and processed samples of pinto bean potentially useful in some food formulations.

Keywords: Pinto bean, domestic processing, functional parameters.

1. Introduction

Legumes refer to the seeds of *Leguminosea,* including peas, beans and pulses. They are the main sources of protein for majority of people (Aremu, 2006; Olaofe, 1993). Legumes are considered as “poor man’s meat” due to their high protein content and low cost compared to meat and meat products (Awolumate, 1983). Recent problems linked to meat consumption have also led to renewed interest in vegetarian diet. This phenomenon is reinforced by the fact that physicians have pointed out that consumers eat too many animal products (rich in saturated fat) and not enough plant foods. The consumption of a great deal of meat increases the risk of cardiovascular diseases and some types of cancer (Davendra, 1995). Therefore, the utilization of seed flour and plant proteins as functional ingredients in food system especially in legumes continued to be of research interest (Aluko andYada, 1995). Furthermore, legumes are known to be superior in terms of the provision of protein without cholesterol, fibre and minerals such as calcium, magnesium and potassium (George and Pamplona–Roger, 2005). Despite these useful constituents that are present in these seeds, its utilization has been ignored because it has been established that there are compounds or substances which act to reduce nutrient intake, digestion, absorption and utilization; they include tannins, saponins, phytates, flavonoids, alkaloids, cyanogenic, glycosides and trypsin (Copeland, 1976; Aremu *et al.,* 2010; Audu et al., 2013).

The pinto bean (Spanish; *Frijol pinto,* literally “painted bean”) is named for its mottled skin (compare with pinto horse), hence it is a type of mottle bean. It is the most common bean in the United States and northwestern Mexico, and is most often eaten whole in broth or mashed and refried. The young pods may also be harvested and cooked as green pinto bean (Lyimo et al., 1992). The plant can be taken in the form of stew and sauces, however, many ethnic groups in Nigeria are not familiar with it unlike the people of Bokkos in Plateau State where it is cultivated and known locally as "Kwakil". It is consumed either in its dry or green form. The leaf is occasionally used as a leaf vegetable, and the straw is used for fodder.

In our earlier work, we have presented the effect of processing methods on the nutritional composition of pinto bean (*Phaseolus vulgaris* L.) seed flour (Audu *et al*., 2011; Audu and Aremu, 2011). Therefore in continuation of our studies on this under–utilized tropical legume, this article considers the effect of processing on functional properties of pinto bean flour. This will provide useful information to the industrialists and others alike on the subsequent incorporation of the studied sample into food products by producing natural, cheap and adaptable functional foods.

2. Materials and Methods

2.1 Collection of the sample

For the purpose of this study, mature seeds of pinto beans (*Phaseolus vulgaris L.*) were collected from a farmer in Bokkos town of Plateau State, Nigeria. The seeds were thoroughly cleaned and sorted to remove stones and bad ones. The processing methods employed were boiling, cooking, roasting, sprouting and fermenting while raw sample served as control.

2.2 Preparation of processed pinto beans seed flour

2.2.1 Raw sample

Cold water was added on 1 kg of pinto bean seeds, left for 4 h and dehulled. The dehulled seeds were dried in the oven at 45°C.

2.2.2 Boiling

The dehulled raw pinto beans (1 kg) were boiled in distilled water at 100°C at the ratio of 1:10 wt/v for 55 min, after which they were drained and oven-dried at 50°C.

2.2.3 Cooking

The cooking was done in an aluminium pot using one part of the dehulled raw seeds (1 kg) to 15 parts of distilled water on a Gallenkamp thermostat hot plate. The seeds were considered cooked when they became soft to touch when pressed between the thumb and fingers. At the end of the cooking time, the boiling water was drained and seeds were sun-dried.

2.2.4 Roasting

Raw seeds (1 kg) were manually dehulled, roasted in fine sand and stirred using the Gallenkamp thermostat hot plate 85^{o}C until a characteristic brownish coloured seed was obtained after 1 h 30 min, which indicated complete roasting. Then, the seeds were cleaned and cooled.

2.2.5 Sprouting

Pinto bean seeds were germinated using sawdust in a locally woven reed basket. The seeds were arranged in layers of sawdust, wetted daily and observed for sprouting. Seeds with sprouts about 1 cm long (3 – 4 days) were picked, washed, dehulled, sliced and dried at 40°C.

2.2.6 Fermenting

The dehulled raw seeds (1 kg) were wrapped in blanched banana leaves and allowed to ferment for 4 days. Fermented seeds were picked, washed, sliced and dried at 40°C.

After all processing treatments were completed; all the raw and processed seed samples were ground into fine flour with a small sample mill (DIETZ, 7311 Dettingentech, West Germany). They were kept in airtight container and put in a deep freezer (-4°C) prior to chemical analyses.

2.3 Functional properties determinations

Foaming capacity and foaming stabilities were determined by the method described by Coffman and Garcia (1977). Full experimental details have been reported by Aremu *et al*. (2007a). Water and oil absorption capacities were measured by the Beuchat (1977) procedure. Oil emulsion capacity and stability were determined by the procedure of Beuchat (1977) as modified by Adeyeye *et al*. (1994). Bulk density was determined using the procedure of Chou and Morr (1979) as modified by Akpapunam and Markakis (1981); Narayana and Narasinga Rao (1984). Lowest gelation concentration was determined by employing the method of Coffman and Garcia (1977) with slight modification as described by Aremu and Ekunode (2008).

3. Results and Discussion

The functional properties of raw and processed pinto bean flour are presented in Table 1. The water absorption capacity ranged from 94.0% in the roasted sample to 140.0% in the boiled sample. The 104.0% reported for the raw sample in this work is lower than the values reported for red kidney bean (165%) (Olaofe et al., 2010) but compared with values for soybean (130%) and various liman bean samples (130 – 142%) (Oshodi and Ekperigin, 1989). The oil absorption capacity (OAC) ranged from 87.0% in the roasted sample to 124.0% in the fermented sample. The 91.0% for the raw flour sample is lower than 280.6% reported for *Clarias lazera* and *Gymarchus niloticus* (148.9%) fish samples (Adeyeye and Adamu, 2005) but higher than values for soya bean (84.4%) and wheat (84.2%) (Lin *et al.*, 1974). Oil absorption is important as oil acts as a flavor retainer and improves the mouth feel of foods (Kinsella, 1979). So pinto bean product would be a good sample for this property.

Foaming capacity (23.8%) for the raw is higher than values for C*larias lazera* fish sample (4.9%), benniseed (18.0%), pear millet (19.0%) (Oshodi *et al.,* 1999), selected sea foods (6-14%) (Ogunlade *et al*., 2005), varieties of legume seeds (7.9 – 15.5%) (Aremu *et al*., 2007a). Pinto bean would be attractive for products like cakes or whipping toppings where foaming is important (Kinsella, 1979). Foaming stability (49.1%, 1 h) for the raw sample is higher than the foaming stability reported for *Clarias lazera* (3.7%, 8 h) (Aremu and Ekunode, 2008), bulma cotton seed (3.0%) (Olaofe *et al*., 1994), kidney bean (5.0%) (Olaofe *et al.,* 2010) but lower than reported values for benniseed (78.0%), gourd seed (61.0%) (Ogungbenle *et al*., 2005). Foaming stability is important since it indicates the performance of whipping agents to maintain the stiffness for as long as possible (Lin *et al.*, 1974). Pinto bean can serve in this capacity. The emulsion capacity for the raw and processed samples (8.5 mL/g in the raw to 11.4 mL/g in the cooked) are lower than reported values for *P. africana* (30.0 mL/g) (Aremu *et al*., 2007b), benniseed, pear millet and quinoa (63.0, 89.0 and 104.0%) (Lin *et al*., 1974) but compared well with reported values of pigeon peas (7 – 11%) (Oshodi and Ekperigin, 1989). Thus, it indicates that pinto bean flour might be useful in the production of sausages, soups and cakes (Kinsella, 1979). The emulsion stability after 1 h, which is the volume of water separated, ranged from 23.6 mL/g in raw to 25.6 mL/g in roasted sample. The value for the raw is lower than values for *P. africana* (38.4 mL/g) (Aremu *et al.,* 2007b), pear millet (34.0%) (Oshodi *et al*., 1999), red kidney bean (50.0%) (Olaofe *et al*., 2010).

The least gelation concentration 8.0% for the raw pinto bean is higher than 6.0% reported for red kidney bean (Olaofe *et al*., 2010) but comparable to African yam beans (8.0% w/v) (Oshodi *et al*., 1997) and three varieties of lima beans flour (8–12% w/v) (Oshodi and Adeladun, 1997). These values indicate that pinto bean flour may be responsible for the fact that stews of pinto bean flour thicken well just like melon seed and gourd seed flours. The bulk density ranged from 0.3800 g/cm^3 in the raw to 0.6900 gcm^3 in the fermented sample. The 0.3500 gcm^3 for the raw is lower than 0.6800 gcm^3 reported for red kidney bean flour but close to 0.4700 gcm^3 reported for soybean flour (Chau and Cheung, 1998).

Table 1: Functional properties of pinto bean

Properties	Raw I	Boiled II	Cooked III	Roasted IV	Sprouted V	Fermented VI	Mean	SD	CV%
Water Absorption Capacity %	104	140	136	94	134	126	122.33	18.90	15.45
Oil Absorption Capacity %	91	121	102	87	113	124	106.33	15.48	14.55
Foaming Capacity %	23.8	24.6	21.5	27.9	24.2	25.2	24.53	8.85	36.07
Foaming Stability %	49.1	56.8	47.2	33.2	42.4	51.3	46.66	8.12	17.40
Emulsion Capacity mL/g	8.5	9.9	11.4	10.9	9.8	10.4	10.15	1.02	10.04
Emulsion Stability mL/g	23.6	33.8	29.3	25.6	30.1	32.2	29.10	3.87	13.29
Least Gelation Capacity %	8	14	10	12	12	10	10.83	1.99	13.27
Bulk Density g/cm^3	0.38	0.63	0.69	0.61	0.42	0.69	0.57	0.10	17.54

The differences in the functional properties between raw and boiled, raw and cooked, raw and roasted, raw and sprouted, and raw and fermented samples are shown in Table 2. Boiling, cooking, sprouting and fermenting increased the water absorption capacity of the pinto bean flour by 36.0, 32.0, 30.0 and 22.0%, respectively when compared with the raw dried seed while roasting lowered it. The decrease implies that heat tended to block the tissue pores. This result is in agreement with report on defatted fluted pumpkin seed flour where it was reported that processing improved the WAC of that seed flour (Fagbemi *et al.,* 2006). The result suggests that the processed seed flour can be used as a thickener in food system (Del Rosario and Flores, 1981).

Processing also affected the OAC significantly ($p \leq 0.05$) (Table 2). Boiling, cooking, sprouting and fermenting increased the oil absorption capacity of the seed flour by 30.0, 11.0, 22.0 and 33.0%, respectively while roasting reduced it by 4.0%. This is in contrast to report that heat treatment generally increased OAC (Olaofe et al., 2010). Observations were made by Esuoso et al. (1998) and Giami (1993) that processing methods such as fermenting, boiling, cooking and roasting enhanced OAC. The result suggests that processed pinto bean flour has less hydrophobic interaction sites (non–polar side chains) so could bind the hydrocarbon side chains of the oil, hence the higher OAC values more than the raw sample (Adebowale and Lawal, 2004). Therefore, pinto bean flour would be potentially useful for their structural interactions in food, especially for flour retention, and to improve palatability and extension of shelf life in bakery or meat products, in which fat absorption is desirable (Fennema, 2000). Processing affected the forming capacity of pinto bean seed flour (Table 2). Boiling, roasting, sprouting and fermenting increased the foaming capacity of pinto bean flour while cooking reduced it. Foaming capacity is dependent on the protein. The reduction in cooking could be as a result of protein denaturation (Adebowale and Lawal, 2004). Foaming stability was also affected by processing. Boiling and fermenting enhanced foaming stability by 7.7% and 2.2%, respectively. Consequently cooking, roasting and sprouting reduced foaming by 1.9, 15.9 and 6.7%, respectively. This indicates that the processed pinto beans gave higher stability.

Table 2: Difference in the functional properties of the raw and processed pinto bean

Properties	I–II	I–III	I–IV	I–V	I–VI	Mean	SD	CV%
Water Absorption Capacity %	–36.0	–32.0	10.0	–30.0	–22.0	26.00	10.29	39.57
Oil Absorption Capacity %	–30.0	–11.0	4.0	–22.0	–33.0	12.00	12.34	61.70
Foaming Capacity %	–0.8	2.3	–4.1	–0.4	–1.4	1.80	1.46	81.11
Foaming Stability %	–7.7	1.9	15.9	6.7	–2.2	6.88	3.44	50.00
Emulsion Capacity mL/g	–1.4	–2.9	–2.4	–1.3	–1.9	1.98	0.67	33,83
Emulsion Stability mL/g	–10.2	–5.7	–2.0	–6.5	–8.6	6.60	3.11	47.12
Least Gelation Capacity %	–6.0	–2.0	–4.0	–4.0	–2.0	3.00	1.05	25.34
Bulk Density g/cm^3	–0.25	–0.31	–0.23	–0.04	–0.31	0.18	0.12	68.33

I = Raw; **II** = Boiled; **III** = Cooked; **IV** = Roasted; **V** = Sprouted; **VI** = Fermented

All the processing methods (boiling, cooking, roasting, sprouting and fermenting) increased emulsion capacity and stability. The increase is such that cooking > roasting > fermenting > boiling > sprouting (2.9, 2.4, 1.9, 1.4, & 1.3%). The emulsion stability was 10.2% (boiling), 8.6% (fermenting), 6.5% (sprouting), 5.7% (cooking) and 2.0% (roasting). Boiling, cooking, roasting, sprouting and fermenting progressively increased the gel forming ability of the pinto bean seed flour. The increase was 9.0% for boiling, roasting and sprouting (6.0%), cooking and fermenting (4.0%), respectively. All the processing methods significantly ($p \leq 0.05$) affected the bulk density of the pinto bean seed flours. Boiling, cooking, roasting, sprouting and fermenting methods increased BD content by 65.8, 81.6, 60.5, 10.5 and 81.6%, respectively.

Figure 1 shows the protein solubility of pinto beans flour. Minimum protein solubility was observed at pH 4 for pinto cooked, pinto fermented, pinto boiled, pinto roasted while that of the raw and sprouted was at pH 5.0. The maximum protein solubility was observed at pH 9-9.40 for both the raw and processed pinto bean flour. At the either side of pH 4-5.2, there was an increase in protein solubility. The pH range of 4-5.0 was the isoelectric point (IEP) of the raw and processed pinto bean flour. Similar observation of this trend has been reported by Fagbemi & Oshodi (1991). Generally, vegetable proteins have been reported to have IEP at about pH 4-5 and show high protein solubility at alkaline pH (Chau and Cheung, 1998). The dependency of protein solubility on pH has been attributed to the change in the net charges carried by the protein as the pH changes. Pinto bean seed flour irrespective of the processing method showed similar protein solubility trend (Fig 1).

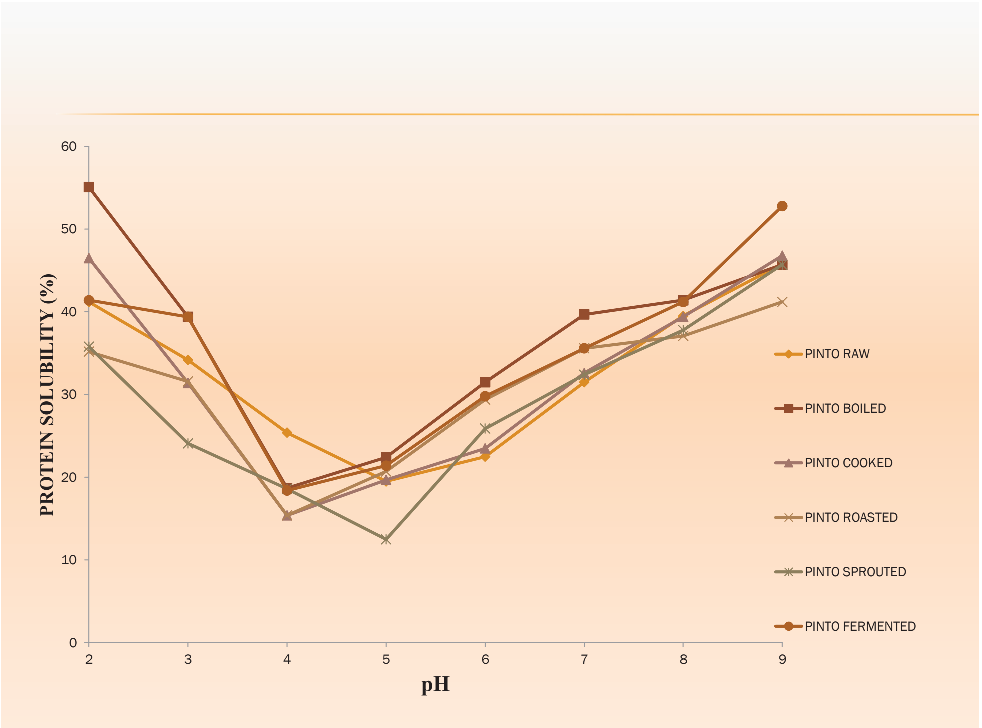

Fig. 1: Protein solubility of pinto bean flour

Boiling, roasting and sprouting reduced the protein solubility ($p \leq 0.05$) of pinto bean flour. Some researchers (Padmashree *et al*., 1987; Giamin and Bakebain, 1992) have reported similar results. Cooked and fermented pinto bean flour enhanced protein. Lin *et al.* (1974) reported similar observation on sunflower flour and soy bean proteins. Therefore, raw dried, cooked and fermented pinto bean flours may be useful in vegetable milk production. The low protein solubility was observed in boiled, roasted and sprouted of the pinto bean flour may be due to heat denaturation and precipitation of the pinto seed protein (Narayana and Narasinga Rao, 1984). Heat-treated protein caused irreversible denaturation leading to association of the polypeptide chains as high molecular weight compounds (Wolf, 1970).

4. Conclusion

Functional properties of raw and processed pinto bean (*Phaseolus vulgaris* L.) seed flour were presented in this study. The results revealed that all the raw and processed pinto bean seed flours were found to posses good water and oil absorption capacities, foaming capacity and stability, emulsion capacity and stability, bulk density and gelation property. The solubility of the flour was high enough, making them potentially useful in some food formulations. It was found that processing significantly ($p \leq 0.05$) affected the content of some functional properties in pinto bean seeds.

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