Food Research 8 (Suppl. 5) : 111 - 122 (2024)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

MINI REVIEW

Functional properties of raw and roasted jackfruit seed flour: a mini review

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Article history:
Received: 5 December 2023
Received in revised form: 3 November 2024
Accepted: 11 December 2024
Available Online: 27 December 2024

Keywords:
Roasted jackfruit seed flour,
Water absorption capacity,
Oil absorption capacity,
Water solubility index,
Foam capacity and stability

DOI:
https://doi.org/10.26656/fr.2017.8(S5).22

Abstract

Jackfruit seed flour is a potential ingredient in food formulation. It can be used in applications of the food industry. Previous research showed that jackfruit seed flour has high water absorption capacity and bulk density, which can be used as a thickener and binding agent in the baking sector. The findings of different studies have shown that the functional properties of jackfruit seed flour are influenced by the roasting temperature and roasting time. The functional properties of jackfruit seed flour such as water absorption capacity, oil absorption capacity, water solubility index, bulk density, foam capacity and foam stability are very important because they determine the suitability of jackfruit seed flour to be used in food production. This review will provide an overview of the functional properties of raw and roasted jackfruit seed flour, which is significant in the processing of food products incorporated with jackfruit seed flour.

1. Introduction

Jackfruit (*Artocarpus heterophyllus*), a member of the Moraceae family and the genus *Artocarpus*, including evergreen or deciduous trees that produce more yield than any other fruit tree species and yields the largest edible fruit, is among the most underutilised fruits (Ranasinghe *et al.*, 2019). Jackfruit consists of a rind, edible yellow flesh, bulbs and seeds (Madrigal-Aldana *et al.*, 2011), and weighs between 10 and 25 kg at maturity (Rahman *et al.*, 1995). Jackfruit seeds account for 18-25% dry weight of the fruit (Mahanta and Kalita, 2015), have an intense, sweet flavour and are covered by golden-yellow fleshy arils (Saxena *et al.*, 2011).They are composed of 11.85% protein, 3.19% fibre, 26.20% carbohydrate, 0.15% ash and 1.006% fat (Gupta *et al.*, 2011; Divekar and Barge, 2017). They are considered waste and can only be consumed after undergoing boiling, steaming, or roasting (Elevitch and Manner, 2006; Gaol *et al.*, 2020).

Jackfruit seeds can be processed into flour by applying various processing techniques such as autoclaving, drying, roasting, boiling and germinating (Eke-Ejiofor *et al*., 2014). The most common methods used for the preparation of jackfruit seed flour are lye peeling, heat processing and mechanical processing (Akter and Haque, 2018). Other than the common methods, boiling, pressure cooking, pan roasting, microwave roasting, baking and fermentation are also used to produce jackfruit seed flour (Setiawan, 2016; Abiola *et al.*, 2018; Borgis and Bharati, 2020; Spada *et al.*, 2020). Jackfruit seed flour has lots of potential, notably as the thickener and binding agent in food systems (Ocloo *et al.*, 2010). It can be used as a thickening agent, stabilising agent and low-cost alternative intermediatory product to produce bakery and extruded products (Chowdhury *et al.*, 2012; Abraham and Jayamuthunagai, 2014; Butool and Butool, 2015). According to Rajarajeshwari and Prakash (1999), it has been proven that adding jackfruit seed flour to deep-fat fried foods greatly reduces the absorption of fat.

One of the most common treatments used on seeds is roasting, prior to grinding into flour (Gahfoor *et al.*, 2018). Roasting of seeds has been reported to enhance the chemical and functional properties of several plant seeds and also decrease the amount of antinutritional substances (Yagoub and Abdalla, 2007; Oluseyi and Temitayo, 2015). It can also alter the physical, chemical and nutritional properties of the seeds, as well as destroy the toxins and pollutants (Rizki *et al.*, 2015; Hatamian *et al.*, 2020). During roasting, the cellular structure of the seed was degraded, resulting in the release of conjugated bound phenolic compounds, including phenolic acids, and the antioxidant capacity of the seed was improved (Dewanto *et al.*, 2002; Ee *et al.*, 2011; Kim *et al.*, 2011). The Maillard reaction that occurs during roasting forms

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eISSN: 2550-2166 /
Published by Rynnye Lyan Resources

melanoidins, which are known to have strong antioxidant properties. This improves the oxidative stability of nuts and seeds (Rizzi, 2003). While increasing other nutrients such as crude protein, roasting of seeds reduced the activities of tannin, phytate, and trypsin inhibitors significantly (Oluseyi and Temitayo, 2015).

The functional properties of jackfruit seed flour are vital in food processing for the production of new products (Akter and Haque, 2018). Raw jackfruit seed flour has high water absorption capacity and good foaming properties, which are crucial factors in determining the physical quality like swelling and softness of bakery products (Kent, 1975; Akter and Haque, 2018). The high oil absorption capacity of raw jackfruit seed flour showed that it has a good flavour retention rate and may be incorporated into food systems such as ground meat formulations (Ocloo *et al.*, 2010). According to previous research, roasting of jackfruit seeds influences the functional properties of jackfruit seed flour such as water absorption capacity, bulk density and foam capacity. It causes the occurrence of gelatinization of carbohydrates and swelling of crude fibre that leads to increased water absorption capacity of jackfruit seed flour (Narayana and Narasinga Rao, 1982). This study is significant as jackfruit seed flour has great potential to be used in food formulations. Therefore, this review focuses on the functional properties of raw and roasted jackfruit seed flour.

2. Physicochemical properties of jackfruit seed flour

The physicochemical properties of jackfruit seed flour give rise to its unique functionality, whether in food applications such as its use as a thickening agent or intermediatory product, as well as its functional properties, which have recently attracted more attention. The physicochemical properties of the flour as reported by the previous studies are listed in Table 1.

According to previous studies on the functional properties of jackfruit seed flour, oven and tray drying are common methods used in the production of jackfruit seed flour for the durationof 8 minutes to 24 hours. From Table 1, the moisture content of jackfruit seed flour ranged between 3.22 and 10.78% (dwb). The moisture content of jackfruit seed flour should be maintained below 10% so that it can be a stable product (Trejo Rodríguez *et al.*, 2021). The differences in moisture content might have resulted from the different methods of drying process and the duration employed in the preparation of the seed flour samples (Sy Mohamad *et al.*, 2019).

The ash content is the organic residue remaining after the organic matter has been burnt away (Ocloo *et al.*, 2010). Table 1 shows that jackfruit seed flour contains 1.27 to 4.19% (dwb) ash content. The high ash content may be attributed to the higher mineral composition in jackfruit seeds (Azeez *et al.*, 2015). It has been claimed that the crude protein content of jackfruit seed flour varies with varietal differences, maturation of the seeds and environmental conditions (Abraham and Jayamuthunagai, 2014). Different researchers reported the crude protein content in jackfruit seed flour ranged between 9.78 and 14.07% (dwb). Crude fat content can be used to predict the swelling behaviour of starch and the baking quality of flour (Guine and dos Reis Correia, 2013). The crude fat content and the crude fibre content of jackfruit seed flour ranged between 0.56 and 4.08% (dwb) and between 1.47 and 31.59% (dwb), respectively. The presence of high fibre content in jackfruit seed flour helps prevent constipation and aids in bowel movements (Siddappa, 1957). The difference in crude fibre content could be attributable to variations in the variety of jackfruit and the process treatment conditions (Ocloo *et al.*, 2010; Nabubuya *et al.*, 2022). The major components of jackfruit seed flours are carbohydrates, making up 62.39 to 83.68% (dwb). The high carbohydrate of jackfruitseed flour makes it an appropriate ingredient in bakery products (Mohd Amin, 2009).

3. Functional properties of raw and roasted jackfruit seed flour

Functional properties represent the complex interaction between the composition, structure, molecular conformation, and physicochemical properties of food components, as well as the nature of the environment in which they are related and assessed (Kinsella and Melachouris, 1976; Kaur and Singh, 2006; Siddiq *et al.*, 2009). Functional properties are defined as the physical and chemical properties of proteins that influence their behaviour in food systems during preparation, processing, storage, and consumption, as well as contribute to the quality and organoleptic properties of food systems (Hermansson, 1979; Söderberg, 2013; Tiencheu *et al.*, 2021). Water absorption, oil absorption, gelation, foaming and emulsifying capacities are the basic functional properties that show the structural behaviour of flour in food systems (Godswill, 2019). The functional properties of raw and roasted jackfruit seed flour by the previous studies are summarised in Table 2.

3.1 Water absorption capacity

Water absorption capacity (WAC) is the quantity of water (moisture) absorbed per gram of sample or protein material of food or flour to reach the desirable consistency and make a high-quality food product (Boye *et al.*, 2010; Farooq and Boye, 2011; Kiosseoglou *et al.*, 2011; Awuchi *et al.*, 2019). WAC of a food product is an

Table 1. Physicochemical properties of jackfruit seed flour.

Components	Drying method	Moisture	Ash	Crude protein	Crude fat	Crude fibre	Carbohydrate	References
Jackfruit seed flour with brown spermoderm	Tray dried at 50-60°C	7.70±0.20	3.97±0.04	11.02±0.46	1.01±0.12	2.36±0.04	81.64±0.00	Tulyathan *et al.* (2002)
Jackfruit seed flour without brown spermoderm		8.57±0.25	3.92±0.03	11.17±0.21	0.99±0.08	1.67±0.11	82.25±0.00	
Jackfruit seed flour	Dried at 60°C for 24 hrs	6.09±0.01	2.70±0.02	13.50±0.06	1.27±0.01	3.19±0.01	79.34±0.06	Ocloo *et al.* (2010)
Jackfruit seed flour with brown spermoderm	Tray dried at 60°C for 16 hrs	10.70±0.00	2.54±0.00	14.02±0.00	4.08±0.00	1.80±0.00	66.86±0.00	Chowdhury *et al.* (2012)
Jackfruit seed flour without brown spermoderm		10.10±0.00	2.24±0.00	12.60±0.00	3.37±0.00	1.47±0.00	70.22±0.00	
Jackfruit seed flour	Dried in hot air drier at	7.76±0.00	2.47±0.00	13.49±0.00	2.32±0.00	3.25±0.00	70.71±0.00	Abraham and
Jackfruit seed flour	Dried at 70°C for 24 hrs	5.07±0.47	2.46±0.28	12.45±0.54	0.77±0.85	3.53±0.71	70.76±7.07	Eke-Ejiofor *et al.* (2014)
Jackfruit seed flour with brown spermoderm	Dried at 600°C for 24 hrs	8.10±0.00	3.92±0.00	11.43±0.00	1.98±0.00	2.80±0.00	74.57±0.00	Sultana *et al.* (2015)
Jackfruit seed flour without brown spermoderm		9.10±0.00	2.70±0.00	11.90±0.00	1.05±0.00	1.53±0.00	75.25±0.00	
Jackfruit seed flour	Dried at 60°C for 24 hrs	9.42±0.07	3.09±0.45	12.14±0.26	1.01±0.21	3.14±0.02	71.20±0.36	Abd El-Aziz and Esmail
Jackfruit seed flour	Sun-dried	6.29±0.00	2.72±0.00	13.23±0.00	1.25±0.00	3.09±0.00	73.42±0.00	Khan *et al.* (2016)
Jackfruit seed flour	Dried at 60°C	3.22±0.16	2.75±0.04	9.78±0.00	0.56±0.01	25.43±0.54	83.68±0.13	Zuwariah *et al.* (2018)
Jackfruit seed flour	Tray dried at 60°C	10.30±0.56	2.93±0.55	13.80±0.62	1.40±0.84	2.90±0.12	68.87±0.23	Shehin *et al.* (2019)
Jackfruit seed flour	Dried at 37°C for 24 hrs	10.78±0.00	2.41±0.00	13.67±0.00	0.75±0.00	3.00±0.00	69.39±0.00	Sy Mohamad *et al.* (2019)
Jackfruit seed flour	Dried at 50-60°C for 16	10.53±0.31	1.27±0.96	13.10±0.98	2.41±0.13	2.50±0.16	Not stated	Maskey *et al.* (2020)
Jackfruit seed flour	Dried at 50°C for 48 hrs	10.72±0.00	2.10±0.00	12.67±0.00	0.75±0.00	3.50±0.00	62.39±0.00	Verma *et al.* (2020)
Jackfruit seed flour	Dried at 60°C	6.54±0.03	4.19±0.13	14.07±0.15	1.30±0.24	31.59±11.14	73.87±1.06	Trejo Rodríguez *et al.*
Jackfruit seed flour	Dried at 70°C for 24 hrs	7.80±0.20	2.60±0.10	10.10±0.10	0.90±0.10	6.40±0.10	71.70±4.40	Nabubuya *et al. (2022)*

Values presented are percentage of dry weight basis (dwb).

indicator of the degree of starch gelatinization since it measures the water holding capacity of the starch after swelling in excesswater, which correlates to the weight of the gel created (Godswill, 2019). Butt and Rizwana (2010) reported that the observed variation in WAC of various foods or flours might be relatedto varying protein concentrations, conformational characteristics, and degree of water interaction. The ability of proteins to bind water is affected by many factors, including size, shape, and the hydrophilic-hydrophobic balance of amino acids in protein molecules, as well as lipids, carbohydrates, and tannins linked with proteins (Adebowale and Lawal, 2004). Besides that, WAC is linked to the ability of flour to produce viscoelastic dough, which gives the dough its flexibility and ability to be stretched and shaped (Godswill, 2019). Food systems that need the preparation of water, such as several baked and meat products use high WAC flours to increase yield and consistency, as well as provide food body (Osundahunsi *et al.*, 2003; Adejuyitan *et al.*, 2009; Bello and Ekeh, 2014; Eriksson *et al.*, 2014; Olatunde *et al.*, 2016; Ngoma *et al.*, 2019).

Some previous studies have shown that the WAC of jackfruit seed flour is increased by heat processing or roasting of jackfruit seeds. Heat processing has also been reported to increase the WAC of African yam bean flour (Eke and Akobundu, 1993), winged bean flour (Narayana and Narasinga Rao, 1982), cowpea flour (Abbey and Ibeh, 1988; Giami, 1993) and flaxseed flour (Shaikh *et al.*, 2020). According to research conducted by Odoemelam (2005), the WAC of raw jackfruit flour (2.3±0.2 mL/g) was lower than the WAC of heat-processed jackfruit flour (3.5±0.1 mL/g) as shown in Table 2. The findings of this study showed that heat processing affects the WAC of native protein in jackfruit flour. In this study, water absorptionof jackfruit flour was increased by heat processing by about 52%. Eke-Ejiofor *et al.* (2014) and Nabubuya *et al.* (2022) reported that WAC of roasted jackfruit seed flour was higher than the WAC of raw jackfruit seed flour. The high WAC of heat-processed jackfruit seed flour was due to the dissociation of the subunit structures of proteins, which have more water-binding sites than the oligomeric protein in raw jackfruit seed flour during heating (Narayana and Narasinga Rao, 1982; Odoemelam, 2005). Gelatinization of carbohydrates and swelling of crude fibre offlour that occurs during heat processing might also have contributed to the increase in water absorption (Narayana and Narasinga Rao, 1982; Ranganathan *et al.*, 2014). In addition, flours contain hydrophilic components, such as polar or charged side chains, mucilage, and raw/crudefibre expansion during heating may also contribute to the increase in WAC (Eltayeb *et al.*, 2011; Shevkani *et al.*, 2015; Timilsena *et al.*, 2016).

3.2 Oil absorption capacity

Oil absorption capacity (OAC), also known as oil binding capacity, is the weight of oil absorbed per weight of protein powder or legume flour (Boye *et al.*, 2010). OAC is a measure of a product or protein's ability to associate with oil with the presence of limited oil (Singh, 2001;Singh *et al.*, 2005). OAC is an essential functional property of food since it influences the mouthfeel, flavour retention, palatability and shelf life of meat and baked goods (Kinsella and Melachouris, 1976; Aremu *et al.*, 2007; Suresh *et al.*, 2015). OAC of flours increases when thenonpolar side chains bind with the oil hydrocarbon side chains in foods and flours and decreases when there are more hydrophilic groups or polar amino acids on the surface of protein molecules (Sathe *et al.*, 1982; Awuchi *et al.*, 2019).

Several previous studies have shown that the OAC of jackfruit seed flours is increased byheat processing or roasting of jackfruit seeds. Odoemelam (2005) and Nabubuya *et al.* (2022) reported that the OAC of heat-processed jackfruit flour (3.1±0.2 mL/g and 196.6±1 .3 g/100 g) was higher than the OAC of raw jackfruit flour (2.8±0.3 mL/g and 129.5±14.2 g/100 g) as shown in Table 2. In other studies, heat processing has also been reported to increase the OAC of winged bean flour (Narayana and Narasinga Rao, 1982), cowpea flour (Abbey and Ibeh, 1988; Giami, 1993), African yam bean flour (Eke and Akobundu, 1993) and flaxseed flour (Shaikh *etal.*, 2020). The increased oil absorption of heat -processed flours is caused by the denaturation and dissociation of constituent proteins that may take place during heating, which unmasks thenon-polar residues or hydrophobic groups from the interior of the protein molecule (Narayanaand Narasinga Rao, 1982; Turan *et al.*, 2015). According to Nabubuya *et al.* (2022), the flours made from roasted jackfruit seed flour have more non-polar side chains as compared to those from raw jackfruit seed flour, which contributes to the high OAC of roasted jackfruit seed flour.

3.3 Bulk density

Bulk density, also known as volumetric density or apparent density, is the mass of several particles of flour material divided by the total volume they fill (Awuchi *et al.*, 2019). Bulk density is a functional property of flours, powders, fine particles, granules, and other divided solids of foods (Awuchi *et al.*, 2019).

Flours with high bulk density are ideal for mixing, suitable to be used in culinary preparations and can be used as stabilisers in processed foods (Akubor and Badifu, 2004; Phuthego, 2014; Awuchi *et al.*, 2019),

https://doi.org/10.26656/fr.2017.8(S5).22

Table 2. Functional properties of raw and roasted jackfruit seed flour.

Functional properties	WAC	OAC	Bulk density (g/mL)	Dispersibility (%)	Swelling power	Least gelation capacity (%)	Solubility (%)	References
Raw jackfruit seed flour	141.00±0.00%	90.20±0.00%	Not stated	Not stated	Not stated	Not stated	Not stated	Singh *et al.* (1991)
Raw jackfruit seed flour	205.00±0.00%	92.60±0.00%	Not stated	Not stated	Not stated	Not stated	Not stated	Tulyathan *et al.* (2002)
Raw jackfruit seed flour	2.30±0.20 mL/g	2.80±0.30 mL/g	0.61±0.03	Not stated	Not stated	16.00±0.00	Not stated	
Roasted jackfruit seed flour	3.50±0.10 mL/g	3.10±0.20 mL/g	0.54±0.04	Not stated	Not stated	18.00±0.00	Not stated	Odoemelam (2005)
Raw jackfruit seed flour	112.00±0.00 mL/100 g	126.90±0.00 mL/100 g	0.80±0.00	30.00±0.00	3.62±0.00 g/g	Not stated	1.80±0.00	Airani (2007)
Raw jackfruit seed flour	25.00±1.67%	17.00±1.37%	0.80±0.02	Not stated	4.77±0.10 g/g	Not stated	Not stated	Ocloo *et al.* (2010)
Raw jackfruit seed flour	203.40±0.00%	97.00±0.00%	0.80±0.00	Not stated	Not stated	Not stated	Not stated	Chowdhury *et al.* (2012)
Raw jackfruit seed flour	2.92±0.00 mL/g	0.88±0.00 mL/g	0.87±0.00	60.33±0.00	5.26±0.00 g/g	17.00±0.00	Not stated	Abraham and Jayamuthu-nagai (2014)
Raw jackfruit seed flour	450.00±70.71%	300.00±0.00%	0.30±0.00	80.50±0.60	8.41±0.33 g/g	12.00±0.00	13.20±0.98	Eke-Ejiofor *et al.* (2014)
Roasted jackfruit seed flour	600.00±0.00%	150.00±70.71%	0.26±0.00	78.75±0.70	6.84±0.56 g/g	12.00±0.00	8.35±5.65	
Raw jackfruit seed flour	104.30±0.00 mL/100 g	116.00±0.00 mL/100 g	Not stated	25.20±0.00	3.62±0.00 g/g	Not stated	1.66±0.00	Butool and Butool (2015)
Raw jackfruit seed flour	72.00±0.20 mL/100 g	86.00±0.50 mL/100 g	Not stated	33.00±0.00	1.46±0.00 g/g	Not stated	2.31±0.00	Islam *et al.* (2015)
Raw jackfruit seed flour	1.10±0.00 mL/g	1.24±0.00 mL/g	Not stated	28.00±0.00	Not stated	Not stated	Not stated	Sultana *et al. (2015)*
Raw jackfruit seed flour	27.80±1.06%	23.60±0.16%	0.69±0.41	Not stated	4.72±0.18 mL	Not stated	Not stated	Abd El-Aziz and Esmail (2016)
Raw jackfruit seed flour	189.00±0.00%	93.00±0.00%	1.31±0.00	Not stated	4.94±0.00 g/g	Not stated	Not stated	Shehin *et al.* (2019)
Raw jackfruit seed flour	2.35±0.17 g/g	1.14±0.07 g/g	0.67±0.00	Not stated	4.12±0.07%	Not stated	9.98±0.80	Sy Mohamad *et al.* (2019)
Raw jackfruit seed flour	182.36±0.03%	89.93±0.20%	Not stated	Not stated	Not stated	Not stated	20.09±0.21	Borgis and Bharati (2020)
Raw jackfruit seed flour	2.34±0.17 g/g	1.12±0.02 g/g	0.65±0.00	Not stated	4.11±0.06%	Not stated	9.90±0.70	Verma *et al.* (2020)
Raw jackfruit seed flour	341.30±9.00 g/100 g	129.50±14.20g/100 g	0.70±0.00	Not stated	39.00±3.40 g/g	Not stated	Not stated	
Raw jackfruit seed flour	373.60±8.80 g/100 g	196.60±1.30 g/100 g	0.50±0.00	Not stated	13.30±1.30 g/g	Not stated	Not stated	Nabubuya *et al.* (2022)

https://doi.org/10.26656/fr.2017.8(S5).22

meanwhile, the low bulk density of flours are advantageous in the production of complementing foods and manufacturing of infant and weaning foods (Nicole *et al*., 2010; Suresh and Samsher, 2013). In addition, several previous studies have showed that the bulk density of jackfruit seed flour is decreased by heat processing ofjackfruit seeds. From Table 2, Odoemelam (2005), Eke-Ejiofor *et al.* (2014) and Nabubuya *etal.* (2022) reported that heat-processed jackfruit flour had a lower bulk density, approximatelyranges between 0.26 and 0.54 g/mL, than the raw jackfruit flour. A similar effect of heat processing on breadfruit seed flour (Giami *et al*., 2000) and flaxseed flour (Shaikh *et al*., 2020) has also been reported. According to Kumar *et al.* (2020), the reduction in bulk density after roasting is related to the formation of a porous structure, which increases porosity and also lowers the moisture content due to the high temperature. Roasting could have caused the starch-starch protein matrix to lose its integrity or caused spaces to form between the starchy endosperm, and thus, decreased the bulk density (Chandrasekhar and Chattopadhyay, 1990). As a conclusion, the loss of moisture and the breakdown of complex substances like starch and proteins contributed to a decrease in bulk density.

3.4 Water solubility index

Water solubility index (WSI) is related to the quantity of soluble solids, and it is frequently used to indicate the degradation of starch molecules and dextrinization, and to calculate the conversion rate of starch during processing (Guha *et al*., 1997; Doğan and Karwe, 2003; Jogihalli *et al.,* 2017). WSI is a measure of the rate and extent of powder materials or particles that dissolve in water (Filli, 2016). WSI is also used to identify the quantity of free polysaccharides or polysaccharides released from the granule when additional water is added (Sriburi and Hill, 2000; Osundahunsi *et al*., 2003; Singh *et al*., 2003).

Previous studies have observed the WSI of flours that are produced from different varieties of plants such as jackfruit, cassava and potato. Based on the study by Noor *et al.* (2014), the WSI of jackfruit seed flour of Gala, Khaja and Durasha were 2.48%, 2.64% and 2.51%, respectively. Nilusha *et al.* (2021) also reported that the WSI of cassava flour of Kirikawadi, MU51, Swarna, Shani and Suranimala were 2.72±0.19%, 1.92±0.25%, 2.17±0.08%, 2.97±0.01% and 4.08±1.40%, respectively. Despite the fact that the flours originated from the same botanical source, variations in WSI can be related to variations in starch structure and morphology, amylose and amylopectin, as well as the presence of salts, proteins, and other components caused by genetic differences (Tortoe *et al*., 2017; Nilusha *et al*., 2021). Additionally, roasting the seed could also increase the WSI of the flour. Nabubuya *et al.* (2022) reported that the WSI of the seed flour increased significantly from 6.5±0.5% to 12.7±0.5% after roasting. WSI is dependent on the morphological structure of starch granules such as size, shape and texture; these determine the extent to which free polysaccharides are released in the presence of water (Osundahunsi *et al*., 2003). The increase in WSI found in formulations containing roasted jackfruit seed flour is most likely due to starch becoming more damaged and being transformed into molecules with lower molecular weight (dextrin) as the temperature increases, causing it to absorb more water and hence increase WSI (Nabubuya *et al*., 2022).

3.5 Foam capacity and stability

Foam capacity, also known as foam expansion, is the ability of a substance in a solution to formfoam following vigorous shaking (Boye *et al*., 2010; Sahoo and Divakar, 2016). Foaming capacity is influenced by the ability of proteins to rapidly adsorb at the air-water interface during whipping and the configuration of protein molecules, whereas foaming stability is influenced by the properties of the multilayer, cohesive film that surrounds the air bubbles andprovides resistance to liquid drainage and droplet coalescence (Grahams and Philips 1976; Sreerama *et al*., 2012). The foaming capacity of food products and food material is determined by the dispersion of gas bubbles in the semisolid or liquid phase and the surface-active properties of a protein, respectively (Sathe *et al*., 1982; Udensi and Okoronkwo, 2006; Godswill, 2019). It is significant in the manufacturing and maintenance of the structure of various food products during and after processing while foam stability is a crucial property of whipping agents sinceit determines how efficient they are at maintaining the whip for as long as possible (Lin *et al*.,1974; Badar, 2013). Flours with good foam capacity and stability are used to make various baked products such as angel cakes and cookies, as well as acting as functional agents in other food and feed formulations (El-Adawy, 2001). Breads, icing and whipped creams are examples of food systems that require high foaming capacity and stability (Atuonwu and Akobundu, 2010). On the other hand, crackers, biscuits, and cookies are examples of foods that require low foaming capacity and stability (Godswill, 2019).

Lin *et al.* (1974) reported that the foamability of flour has been found to be linked to the quantity of native protein. Denatured protein has a lower foam stability than native protein (Yasumatsu *et al*., 1972). Protein denaturation can explain the lower foam capacity and

https://doi.org/10.26656/fr.2017.8(S5).22

stabilityof heat-processed flours since proteins are heat-labile (Odoemelam, 2005). In addition, several studies have reported that foam capacity and stability of flours are decreased by heat processing or roasting of seeds. Odoemelam (2005) reported that heat processing significantly decreased the foam capacity and stability of jackfruit flour. The results showed that foam capacity and stability of heat-processed jackfruit flour was lower as compared to raw jackfruit flour. A similar effect of heat processing on foam capacity and stability of African breadfruit seed flour(Giami *et al.*, 2000), okra seed flour (Adelakun *et al.*, 2012) and winged bean flour (Narayana and Narasinga Rao, 1982) has also been reported.

The lower values of foamability associated with roasted flour may be related to high protein-protein interaction, leading to the production of aggregates that hinder foam formation (McWatters and Cherry, 1977) and decreased nitrogen solubility owing to denaturation (Yasumatsu *et al.*, 1972). According to Onimawo and Egbekun (1998), foam capacity and stability can be affected by many factors, including temperature, protein type, and preparation method. Proteins are often responsible for foaming properties, and heating reduces protein solubility, which might explain why roasted samples have a lower foaming capacity (Eke and Akobundu, 1993).

4. Conclusion

Jackfruit seed flour exhibits good functional properties, such as water and oil absorption capacity, bulk density and swelling power. The functional properties of jackfruit seed flour were affected by the roasting of the jackfruit seeds. Roasting caused the increase in water absorption capacity, oil absorption capacity and water solubility index of jackfruit seed flour. On the other hand, it also caused a reduction in bulk density, foam capacity and foam stability of the flour. Based on the review, raw jackfruit seed flour is recommended for future product development. For applications of raw jackfruit seed flour in bakeries and other food products, further research works and cooperation among jackfruit seed flour processors and food manufacturers is necessary.

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