Heating and Biochemical processing of *Kariya* (*Hildegardia bateri*) seeds: Chemical composition, antinutrients and functional properties

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Abstract

This study evaluated the effects of processing methods on chemical composition, physicochemical and functional characteristics of defatted and full fat flour samples from processed *kariya* seeds. The seeds were cleaned and subjected to heating processes (cooking and autoclaving) and biochemical processes (germination and fermentation), the seeds were dried and milled to flour. A portion was defatted and another portion left as full fat. The flour samples were analysed for the selected parameters using standard methods. The results showed that the bulk density ranged between 0.52-0.75 g/ml. The oil absorption and water absorption capacities ranged from 65.50–144.60% and 46.40–218.50% respectively. The water absorption and swelling capacities of the defatted samples increased with temperature increase. All processing treatments were found to increase protein content (22.16–49.94%) and in-vitro digestibility (27.86–82.63%). Both the heating and biochemical processes reduced the level of antinutrients significantly. In conclusion, the *kariya* flour samples subjected to both fermentation and germination had better chemical composition, physico-chemical and functional properties.

Introduction

*Kariya* (*Hildegardia bateri*) is a rainforest tree of about 30 m in height. It belongs to the mallow family- *Malvaceae* and to the subfamily *Sterculiaceae* [1]. In West Africa, *kariya* is used as ornamental tree because of its bright beautiful flowers which blossom during the dry season. The flowers, which are usually borne on leafless branches, mature into one-seeded pods, each about 5 mm in length, bearing a peanut-like seed in a nutshell. The mature pods drop completely when dry and are disposed as refuse in many places. The kernels are eaten raw or roasted like groundnuts in some part of West Africa countries [2], it is also processed and used as condiments in traditional food preparations. The proximate composition (17.5, 37.5, 6.5, 2.5% of crude protein, fat, crude fibre and ash respectively) and fatty acid profile of these biomaterials provide the basis for their use as food or oil [3]. It contain some antinutrients according to the report of Ikujenlola et al. [4], some of which might be responsible for the death of experimental animals during feeding trials.

Previous works on *kariya* showed that it is rich in protein (17.5%) and fat (37.5%). High quality protein products such as protein concentrate, isolate and hydrolysate with good functional properties and high *in vitro* protein digestibility could be obtained from *kariya* seed flour [3,5-7]. One of the methods employed to increase the protein content and improve the functional properties of oil seed is to reduce/ remove the fat thereby extending the shelf life of the flour. This can also increase the functionality and hence application of the flour in food formulations. However, the utilisation of any food protein flour as foods or food ingredients will largely depend on its physicochemical and functional characteristics as well as the safety of such product.

Food processes such as germination, fermentation, autoclaving, boiling, roasting, etc. have been reported to have positive effect on the quality parameters (sensory, functionality, safety, etc.) of food products [8].

This study was designed to investigate the effect of various processing methods on physico-chemical and functional properties of *kariya* kernel flour with a view to providing useful information for its possible application in food system.

Materials and Methods

Materials

*Kariya* pods were gathered from *kariya* trees in Obafemi Awolowo University, Ile-Ife, Nigeria. The reagents used were of analytical grade and were purchased from Sigma Aldrich chemical company, USA.

Methods

Processing of *kariya* whole and defatted flour samples

The matured pods were ruptured to remove the seeds and the seeds were manually dehulled and winnowed. The seeds were divided into seven portions, one portion served as the control (i.e. unprocessed/raw seed) and each of the remaining six portions was subjected to different processing treatments: cooking/boiling (at 100°C, 1 h), autoclaving (at 121°C, 15 psi, 30 min), roasting (at 100°C, 1 h), germination (at 28 ± 2°C, 96 h), fermentation (at 28 ± 2°C, 96 h) and combination of germination (at28 ± 2°C, 96 h) and fermentation (at 28 ± 2°C, 96 h).

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The processed seeds were dried at 60°C for 12 h in the cabinet drier, milled and sieved into fine flour through 200 µm mesh sieve. Flour sample from each processing method was divided into two portions. The first portion was left as full fat flour sample and the second portion was defatted using cold acetone by stirring over magnetic stirrer for 4 h (1:4 w/v; flour: acetone) at room temperature.

**Proximate Composition of processed *kariya* seed flour samples**

The proximate composition (moisture, protein, crude fibre, fat, ash and carbohydrate) of processed *kariya* seed flour was determined using standard method of AOAC [9]. The energy value was calculated using Atwater factor according to Alobo *et al*. [10].

**Moisture**

Moisture content of the samples was determined by the standard AOAC [9] official method. The results were expressed as percentage of dry matter shown in Equation 1;

\[
\text{Moisture content (%)=}(W_1-W_2)/W_1 \times 100 \%
\]

\[
W_1=\text{weight of flour before drying}
\]

\[
W_2=\text{weight of flour after drying}
\]

**Protein**

The protein content of the samples was determined using the AOAC [9] method. The nitrogen content was obtained as shown in Equation 2 and multiplied by 6.25 to obtain crude protein content.

\[
\text{Nitrogen content,} NC=\frac{(1.401 \times 0.2 \times (A1-B1))}{\text{Sample weight}} \times 6.25
\]

\[
A1=\text{titre value of sample}
\]

\[
B1=\text{titre value of blank}
\]

\[
\text{Protein content} = 6.25 \times NC
\]

**Crude fat**

Crude fat was determined by the AOAC [9] method using Soxhlet apparatus (Sunbim, India). The quantity of oil obtained was expressed as percentage of the original sample used as shown in Equation 3;

\[
\text{Crude fat (%)=}(W_4-W_5)/W_6 \times 100 \%
\]

\[
W_4=\text{weight of flask+oil}
\]

\[
W_5=\text{weight of empty flask}
\]

\[
W_6=\text{weight of sample}
\]

**Ash**

Ash content of the samples was determined by the AOAC [9] method using muffle furnace (Carbolite AAF1100, United Kingdom). Ash content was expressed as percentage of the weight of the original sample as shown in Equation 4;

\[
\text{Ash content(%)=}(W_7-W_8)/W_9 \times 100 \%
\]

\[
W_7=\text{weight of crucible after ashing}
\]

\[
W_8=\text{weight of crucible after oven drying}
\]

\[
W_9=\text{weight of sample}
\]

**Crude fibre**

Crude fibre was determined as described by AOAC [9] using 2 g (W_{12}) of the samples. The crude fibre was obtained using the equation below (Equation 5);

\[
\text{Crude fibre (%)=}=(W_10-W_11)/W_{12} \times 100 \%
\]

\[
W_{10}=\text{weight of crucible after ashing}
\]

\[
W_{11}=\text{weight of crucible after oven drying}
\]

\[
W_{12}=\text{weight of sample}
\]

**Carbohydrate**

Carbohydrate was expressed as a percentage of the difference between the addition of other proximate composition and 100 as shown in Equation 6;

\[
\text{Carbohydrate (%)=}=100-\left(\text{moisture content+crude fat+crude fibre+ash content+crude protein}\right)
\]

**In vitro protein digestibility determination**

In vitro protein digestibility of samples was measured according to the method described by Chavan *et al*. [11]. Protein digestibility was obtained by using the equation shown below;

\[
\text{In vitro protein digestibility (%)=}= \left(\frac{I-F}{I}\right) \times 100
\]

where: I- protein content of sample before digestion
protein content of sample after digestion

**Determination of antinutrient content**

The concentrations of some selected antinutrients (tannin, oxalate, saponin and phytate) were determined.

**Determination of Tannin**

The modified vanillin–hydrochloric acid (MV–HCl) method of Price *et al*. [12] was used. The following calculation was adopted:

\[
\text{Tannin}=(Xmg/ml \times 10 ml)/(0.2 g)=50 \times \text{mg/g}
\]

where X-value obtained from standard catechin graph

**Determination of oxalate**

Oxalate was determined by the method of Falade *et al*. [13]. The oxalate was calculated as the sodium oxalate equivalent as shown in equation below.

\[
1 \text{ ml of 0.05 M KMnO}_4= 2 \text{ mg sodium oxalate equivalent/ g of sample.}
\]

**Determination of saponin**

The spectrophotometric method of Brunner [14] was used for saponin analysis.

\[
\text{Saponin}=(\text{Absorbance of sample} \times \text{dil.factor} \times \text{Gradient of standard graph curve})/(\text{Sample weight} \times 10,000)(\text{mg/g})
\]

**Determination of phytate**

The phytate content of the samples was determined adopting the method described by Reddy *et al*. [15]. The concentration of the FeCl₃ is 1.04%w/v and Mole ratio of Fe to phylate=1:1 100 x weight of sample
Concentration of phytate phosphorous=Titre value x 0.064.

Physicochemical and functional properties determination of kariya seed flour

Bulk density was determined by the method of Okezie and Bello [16]. The pH was measured by making a 10% w/v suspension of the sample in distilled water and the pH of the suspension was measured with a pH meter (Model HI 9812F, Hanna instrument, Woonsocket RI USA). Water absorption capacity (WAC) was determined at room temperature and at temperatures ranging from 60 to 90°C using the method of AACC [17]. Oil absorption capacity (OAC) of the samples was determined by the centrifugation method described by Beuchat [18]. Swelling capacity (SC) was determined using the method described by Takashi and Sieb [19]. Emulsifying activity index (EAI) and emulsifying stability (ES) at natural pH was determined by the method described by Gbadamosi et al. [20].

Statistical analysis

All determinations were carried out in triplicates and results were subjected to analysis of variance (ANOVA) and means separated by Duncan Multiple Range Test.

Results and discussion

Proximate composition of full fat and defatted flour samples of processed kariya seeds

The proximate composition of processed kariya flour samples is shown in Table 1. The moisture contents of the flour samples produced from various processing methods varied significantly (p<0.05) between 3.50 and 20.33% with roasted sample (R) having the lowest and defatted flour of germinated-fermented sample (DGF) having the highest. Low moisture content increases shelf stability [21] while high moisture content encourage proliferation of spoilage microorganism in food systems.

The fat content of the samples ranged between 6.10 and 50.98%. There was significant increase (p<0.05) in fat content of fermented and germinated-fermented samples however, significant decrease was observed in germinated sample. Li et al. [22] reported a significant decrease of fat content when groundnut seeds were germinated. This could be due to the increased activities of lipolytic enzymes during germination which hydrolyses fat components into fatty acid and glycerol [23].

The crude fibre content ranged from 0.15 to 2.10%. The crude fibre content of defatted flour samples was lower than those of full fat flour samples. Similar observation was also reported by OCheme et al. [24] for defatted groundnut.

Protein contents varied from 22.16-49.94% with raw sample having the lowest value while defatted fermented sample had the highest value. All the processing conditions increased protein content significantly. Fawale et al. [25] reported increase in protein content of cooked and fermented kariya seeds. The protein contents of defatted flour samples were significantly higher (p<0.05) than the protein contents of full fat flour samples. Higher protein content observed in fermented sample is similar to the observations by Sathya and Siddharaju [26] on fermented Pakia roxburghii (yongohak) seeds and Fawale et al. [25] on fermented kariya seed. This could be attributed to structural proteins that are integral parts of the microbial cells [27]. Germination process also increased protein content and this could be attributed to the net synthesis of enzymes by germinating seeds which might have resulted in the production of some amino acid during protein synthesis[28].

It was observed that carbohydrate reduced in all the full fat samples. However, defatting process caused significant increase in the carbohydrate content of the treated flour. Similar observation was reported by Fawale et al. [25] and Kang et al. [29].

There was significant difference (p<0.05) in the ash content of the samples. The values ranged from 2.88-7.65% with defatted roasted sample having the highest value while boiled sample had the lowest value. The range of ash content values are within the range of values (2.11-7.98%) reported by Udoh [30] for full fat and defatted flour of fluted pumpkin seed. Defatting process resulted in increase in ash content, this was similar to observations reported by Ogunsina et al. [31] and Adeshina et al. [5] for kariya kernel flour. Ash content is an indication of the total mineral content in food.

The energy value varied from 330.15-613.40 kcal with defatted germinated-fermented sample having the lowest value while full fat germinated-fermented sample had the highest energy value. There was significant decrease (p<0.05) in the energy value of boiled, germinated and all defatted flour samples but there was significant increase (p<0.05) in the energy value of fermented and germinated-fermented sample.

| Sample code | Fat (g/100g) | Crude fibre (%) | Protein (%) | Moisture (%) | Ash (%) | Carbohydrate (%) | Energy value (kcal) | In vitro protein digestibility (%)
|-------------|--------------|-----------------|-------------|--------------|---------|------------------|--------------------|---------------------|
| Ra          | 32.05±0.15   | 0.58±0.03       | 22.16±0.16  | 5.95±0.10    | 4.43±0.23 | 37.85±0.22      | 28.44±0.15         | 27.86±0.65          |
| B           | 31.35±0.20   | 0.18±0.25       | 27.00±0.20  | 4.23±0.53    | 2.88±0.18 | 28.72±0.55      | 05.88±1.25         | 33.33±0.27          |
| R           | 37.00±0.65   | 0.30±0.05       | 24.90±0.50  | 3.50±0.10    | 5.30±0.30 | 34.61±0.82      | 571.04±1.82        | 31.58±0.49          |
| A           | 32.53±0.33   | 0.68±0.08       | 27.56±0.46  | 3.85±0.30    | 4.98±0.33 | 30.43±0.42      | 524.73±2.14        | 34.68±0.52          |
| G           | 28.40±0.55   | 0.25±0.05       | 31.50±0.50  | 4.78±0.13    | 4.48±0.08 | 30.40±0.81      | 504.00±3.15        | 37.49±0.44          |
| F           | 49.2±0.08    | 1.60±0.11       | 34.13±0.10  | 5.35±0.10    | 3.60±0.20 | 52.78±0.92      | 603.57±0.74        | 46.15±0.45          |
| GF          | 50.98±1.18   | 2.10±0.25       | 33.6±0.43   | 5.38±0.18    | 3.33±0.03 | 4.69±0.67       | 613.40±7.82        | 45.35±0.35          |
| DB          | 9.13±0.03    | 0.18±0.01       | 32.81±0.60  | 7.13±0.13    | 4.20±0.10 | 46.59±0.72      | 399.77±6.06        | 75.04±0.44          |
| DR          | 9.19±0.38    | 0.20±0.09       | 33.88±0.44  | 4.80±0.25    | 7.65±0.15 | 49.19±0.34      | 419.90±2.27        | 72.61±0.31          |
| DA          | 6.10±0.02    | 0.45±0.05       | 33.50±0.49  | 6.85±0.05    | 6.45±0.15 | 46.65±0.38      | 375.50±0.20        | 76.34±0.48          |
| DG          | 10.3±0.18    | 0.15±0.05       | 38.77±0.35  | 7.65±0.65    | 6.40±0.30 | 36.70±0.43      | 94.85±2.58         | 79.70±0.40          |
| DF          | 12.63±0.23   | 1.25±0.25       | 49.94±0.24  | 12.38±0.68   | 5.83±0.23 | 22.10±1.29      | 401.83±2.57        | 82.63±0.47          |
| DGF         | 8.83±0.75    | 1.80±0.33       | 39.97±0.55  | 20.33±1.99   | 6.25±0.36 | 22.75±0.90      | 330.15±2.89        | 81.27±0.22          |

Values reported are means±standard deviation of triplicate determinations. Means values bearing different superscript roman letters are significantly (P < 0.05) different from one another.

Ra: Raw; Boiled: R; Roasted: A; Autoclaved: G; Germinated; F; Fermented; GF; Germinated fermented; DB: Defatted boiled; DR: Defatted roasted; DA: Defatted autoclaved; DG: Defatted germinated; DF: Defatted fermented; DGF: Defatted germinated fermented.
The low energy value observed in boiled, germinated and all defatted flour samples could be attributed to the decrease in fat content of the flour samples.

**In vitro** protein digestibility of full fat and defatted processed kariya seed flour

The results of *in vitro* protein digestibility of full fat and defatted flour of processed kariya seed are shown in Table 1. The *in vitro* protein digestibility of the samples ranged from 27.86–82.63% with the raw sample having the lowest value (27.86%) and the defatted fermented sample having the highest value (82.63%). *In vitro* protein digestibility significantly increased in all the samples. This agrees with the observation of Adu et al. [32] that heat processing improves protein digestibility significantly. This might be attributed to the effect of heat on the protease inhibitor and denaturation of protein especially globulin which commands the open up of their structure and increase the chain flexibility and hence less resistance against digestive proteases [26]. The increase in protein digestibility could as well be attributed to the degradation or reduction of antinutrients such as tannins and phytic acid by microbial enzymes, fermentation, germination and heat treatments [33,34].

**Physicochemical and functional properties of full fat and defatted flour of processed kariya seed flour**

The results of physicochemical properties (bulk density and pH) and functional properties of full fat and defatted kariya seed flour samples are presented in Table 2.

**Bulk density**

The bulk density of the samples ranged between 0.52-0.75 (g/ml). The range of values reported in this study compared favourably with the result (0.57 g/ml) reported by Adebayo et al. [5] for defatted kariya flour and processed pinto bean (0.42-0.69 g/ml) reported by Audu et al. [35] but lower than the value (1.00- 1.04 g/ml) reported by Akpossan et al. [36] for *Imbrasia oyemensis* full fat flour and defatted flour. There was significant decrease (p<0.05) in the bulk density of germinated sample which could be as a result of the breakdown of high molecular weight macromolecules to low molecular weight molecules [26]. The increase in protein digestibility could as well be attributed to the degradation or reduction of antinutrients such as tannins and phytic acid by microbial enzymes, fermentation, germination and heat treatments.

**Oil absorption capacity (OAC) of processed kariya seed flour**

The OAC of the samples ranged from 65.50-144.60%. The trend was similar to the OAC values (63–83%) reported by Adegunwa et al. [41] for benni seed. The OAC of roasted, autoclaved, fermented and germinated-fermented kariya samples were observed to be lower than the OAC of raw sample. There was increase in the OAC of boiled and germinated samples. The boiled full fat flour sample had the highest OAC (109%) among the full fat flour samples and the increase in fat absorption is associated with heat dissociation of the proteins and denaturation which is expected to unmask the nonpolar residue from the interior of protein molecules [42]. Similar observation was reported by Fawale et al. [25] for cooked unfermented kariya. Germination increased oil absorption capacity and similar observation was reported by Wisansiyasa [43] for fluted pumpkin seed.

There was significant increase (p<0.05) in the OAC of the defatted samples compared to the full fat samples and this agrees with the value reported by Ogunsina et al. [31] for full fat and defatted moringa seed flour. This shows that defatting increased oil absorption capacity and defatted flour can find good applications in food formulation where high OAC is required such as in meat, pastries and bakery products production.

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**Table 2. Physicochemical and functional properties of raw and processed Kariya flour**

| Sample Code | Bulk Density (g/ml) | pH | Water Absorption Capacity (%) | Oil Absorption Capacity (%) | Emulsifying Activity Index (g/mL) | Emulsifying Stability Index (%) |
|-------------|---------------------|----|--------------------------------|-----------------------------|----------------------------------|-------------------------------|
| Ra          | 0.63 ± 0.00 a       | 6.84 ± 0.05 a  | 46.40 ± 1.60 a                | 91.30 ± 2.50 a             | 11.66 ± 0.99 b                  | 105.62 ± 0.40 d               |
| B           | 0.55 ± 0.01 b       | 6.34 ± 0.01 b  | 143.50 ± 7.5 b                | 109.00 ± 4.00 b            | 21.48 ± 0.11 b                  | 113.78 ± 0.80 c               |
| R           | 0.60 ± 0.02 b       | 6.03 ± 0.02 b  | 80.20 ± 6.40 b                | 89.90 ± 2.90 b             | 21.33 ± 0.03 b                  | 108.74 ± 0.50 b               |
| A           | 0.74 ± 0.00 c       | 6.24 ± 0.02 c  | 53.00 ± 4.80 c                | 65.50 ± 3.30 c             | 21.53 ± 0.16 c                  | 121.10 ± 0.25 d               |
| G           | 0.56 ± 0.00 d       | 6.10 ± 0.08 d  | 92.60 ± 7.80 d                | 99.10 ± 3.90 d             | 21.90 ± 0.70 d                  | 128.26 ± 0.18 d               |
| F           | 0.73 ± 0.01 e       | 5.64 ± 0.03 e  | 130.80 ± 8.20 e               | 80.70 ± 3.70 d             | 25.42 ± 0.18 e                  | 134.62 ± 0.43 e               |
| GF          | 0.75±0.05 f         | 5.33 ± 0.03 f  | 143.70±6.90 f                 | 86.10 ± 3.50 f             | 22.32 ± 0.22 f                  | 130.76 ± 0.67 f               |
| DB          | 0.52 ± 0.01 f       | 6.37 ± 0.02 f  | 218.50±5.90 f                 | 144.60 ± 0.40 f            | 16.45 ± 0.06 f                  | 104.70 ± 0.88 f               |
| DR          | 0.58 ± 0.01 g       | 6.09 ± 0.02 g  | 96.10±2.50 g                  | 103.00±4.40 g             | 16.26 ± 0.13 g                  | 102.10 ± 1.17 g               |
| DA          | 0.57 ± 0.01 h       | 6.27 ± 0.02 h  | 75.90±6.90 h                  | 117.20±6.20 h             | 18.34 ± 0.09 h                  | 108.76 ± 0.29 h               |
| DG          | 0.62 ± 0.00 i       | 6.23 ± 0.02 i  | 102.00±4.60 i                 | 119.60±7.40 i             | 17.70 ± 0.09 i                  | 112.61 ± 0.48 i               |
| DF          | 0.65 ± 0.01 j       | 5.72 ± 0.01 j  | 179.10±7.30 j                 | 117.80±6.40 j             | 20.63 ± 0.18 j                  | 123.97 ± 0.29 j               |
| DGF         | 0.63 ± 0.01 k       | 5.50 ± 0.03 k  | 175.90±6.90 k                 | 108.00±0.80 k             | 18.79 ± 0.60 k                  | 118.43 ± 0.32 k               |

Values reported are means ± standard deviation of triplicate determinations. Mean values bearing different superscript roman letters are significantly (P<0.05) different from one another. Ra: Raw; B: Boiled; R: Roasted; A: Autoclaved; G: Germinated; F: Fermented; GF: Germinated fermented; DC: Defatted boiled; DR: Defatted roasted; DA: Defatted autoclaved; DG: Defatted germinated; DF: Defatted fermented; DGF: Defatted germinated fermented.
Water absorption capacity (WAC) of raw and processed kariya seed flours

All the processing methods influenced WAC and there was significant difference (p<0.05) in WAC of all the samples. Among all the processing conditions, autoclaved samples had the lowest (53%) while germinated-fermented samples had the highest WAC (143.70%). Water absorption capacity of all the processed flours significantly increased compared to the raw sample. According to Oloyede et al. [39] the low water absorption capacity recorded for raw sample is an indication of intact starch granules in the raw flour.

Defatted flour samples exhibited higher WAC than the full fat flour samples. The WAC of defatted treated samples ranged from 75.90–218.50%. The reduction in fat content resulted in increase in protein and carbohydrate and subsequent increase in WAC. According to Sila and Malleshi [44] flours with high WAC has more hydrophilic constituent as polysaccharides. Product of high WAC can serve as good thickening agent and be used as a thickener or gelling agent in various food products.

Emulsifying activity index (EAI) and emulsifying stability (ES) of raw and processed kariya seed flour

At natural pH of the samples, the EAI ranged from 11.66–25.42 m²/g with significant differences (p<0.05) between the highest and lowest EAI values. Among the treated samples, fermented sample had the highest EAI value (25.42 m²/g) and similar observation was reported by Fawale et al. [25]. The high EAI value observed in fermented sample could be attributed to its high fat content and the hydrolysis of higher molecular protein peptide to lower molecular protein peptide with high lipophilic ends [45].

The emulsion stability of samples ranged from 102.10–134.62% with fermented sample having the highest value (134.62%) and defatted roasted sample had the lowest value (102.10%). Emulsion stability shows the ability of protein to impact strength to an emulsion for resistance to stress and changes or to reduce the interfacial tension between oil and water in the emulsion [46]. However, decrease in surface tension of the oil droplet by providing electrostatic repulsion on the surface of the oil droplet prevents coalescence and this brings about emulsion stability [47].

Fermentation significantly increased EAI and ES and this agrees with the report of Oloyede et al. [39] for Moringa oleifera seed. With this property it gives an indication that the flour can be used in certain food systems e.g. frozen desserts, whippings, toppings, mayonnaise, yoghurt and salad dressing.

Emulsion capacity is the maximum quantity of oil that can be emulsified by protein dispersion whereas emulsion stability indicates the ability of an emulsion with a known composition to remain unchanged [48].

Influence of temperature on water absorption capacity (WAC) of raw and processed kariya seed flour

The WAC of raw and processed kariya flour as influenced by temperature changes is presented in Figure 1. The WAC of all the samples increased as temperature increases. Gradual increase in WAC was observed in boiled, fermented and germinated-fermented processed full fat kariya flour samples and the defatted flour samples as the temperature increases. A spontaneous increase was observed in the autoclaved, roasted and germinated full fat flour samples. The difference in protein structure and the presence of different hydrophilic carbohydrates as a result of variation in processing treatment might be responsible for variation in the WAC of the flour samples. The water absorption capacity of defatted kariya seed flour is shown in Figure 2. Similar observation was reported for the full fat flour samples but the defatted flour samples had higher water absorption capacities. The removal of fat from samples exposed the water binding sites on the side chain groups of protein units previously blocked in a lipophilic environment thereby leading to an increase in WAC values in defatted flour [49].

According to Lagnika et al. [50], water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food.

![Influence of temperature on water absorption capacity of raw kariya flour and whole flour of kariya subjected to different processing treatments](image)

**Figure 1.** Influence of temperature on water absorption capacity of raw kariya flour and whole flour of kariya subjected to different processing treatments.
Influence of temperatures on swelling capacity of raw and processed kariya seed flour

The results of the influence of temperature changes on swelling capacity of full fat and defatted kariya flour samples are shown in Figures 3 and 4 respectively. Swelling capacity increased as the temperature increases and the highest swelling capacity was observed at the highest temperature (90°C) which ranged from 134.00-264.00°C for full fat samples and 203.00–309.67°C for defatted flour samples. The lowest swelling capacity was observed at the lowest temperature (60°C). The swelling capacity at 60°C ranged from 69–203°C for full fat flour and 104–288°C for defatted flour samples. This agrees with the result reported by James et al. [51] that temperature increase caused vigorous starch vibration which breaks intermolecular bonds and thereby allowing hydrogen bonding sites to accommodate more water molecules. Also, Bhat and Riar [52] reported that swelling power of starches increased with increase in temperature and this could be attributed to reduction in gelatinization temperature.

Antinutrients of raw and processed kariya seed flour

The antinutrients of processed kariya flour samples are presented in Table 3. It was observed that the various processes resulted in the reduction of the selected antinutrients. The level of reduction ranged from 0 to 100%.
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It was observed that tannin in the processed flour samples reduced in all the samples compared with the raw sample. The germinated samples recorded significant reduction in the level of tannin, however, it was observed that fermented, germinated/fermented samples did not follow the pattern. It was in contrast to the observation of Rajan et al. [53] for the sprouted and fermented five varieties of sorghum but it agrees with the observations reported by Osman [33] and Satiya and Siddharaju [26] for traditionally fermented pearl millet for "loloh" preparation and Pakia roxburghii (locust bean) respectively. The increase in the tannin content of the fermented kariya sample could be attributed to hydrolysis of condensed tannins such as proanthocyanidin. The increase in tannin content may adversely affect the nutritional quality of fermented kariya flour. According to Sarwar et al. [54], high tannin concentration in diet may cause depressed microbial enzyme activities during intestinal digestion however in spite of the known adverse action on protein digestibility, seed tannins might exert a beneficial antioxidant activity and contribute to diseases prevention.

The heating and biochemical processes into which the kariya seeds were subjected reduced the level of the saponin present in the flour samples. The process of defatting also enhanced the reduction of the antinutrient. This observation agrees with the report of Kaur et al. [55] that extracting solvent has potential to reduce the inherent antinutrients due to solubility of the components.

The heating processes promoted reduction in the level of oxalate present in the processed kariya flour samples. Furthermore, it was observed that fermentation process caused a noticeable reduction in oxalate content better than combination of germination and fermentation processes. Defatted flour samples had lower oxalate content compared to full fat kariya flour samples.

Phytate content of defatted flour samples were lower than those of full fat samples. Heating processes reduced the level of phytate in the heat processed samples but not as much as in the biochemically processed samples. The germinated and germinated/fermented samples were of lower phytate content. Phytates according to Gupta et al.[56] are referred to as heat stable antinutrients. Similar observation was reported by Kaur et al. [55] who recorded 88.30% reduction in phytate content when germinated pearl millet sprouts were fermented with selective culture media. According to Gupta et al. [56], natural fermentation caused large reduction in phytic acid in rice flour by the action of microbes as well as grain phytase. This reduction could be attributed to the activity of the endogenous phytase enzyme from the raw ingredient and inherent microorganisms which are capable of hydrolysing the phytic acid in the fermented food preparations into inositol and orthophosphate [57].

### Table 3. Anti-nutrients value of raw and processed Kariya seed flour (mg/100 g)

| Sample | Tanin | Saponin | Oxalate | Phytate |
|--------|-------|---------|---------|---------|
| Ra     | 1.58 ± 0.13a | 2.37 ± 0.17a | 4.29 ± 0.55a | 14.72 ± 0.64a |
| B      | 0.53 ± 0.13a | 1.89 ± 0.06a | 1.42 ± 0.09a | 7.68 ± 0.64a |
| R      | 1.06 ± 0.13a | 1.51 ± 0.01a | 1.98 ± 0.22a | 7.04 ± 0.64a |
| A      | 0.59 ± 0.06a | 1.46 ± 0.01a | 1.59 ± 0.15a | 8.32 ± 0.64a |
| G      | 0.86 ± 0.07a | 1.57 ± 0.20a | 2.86 ± 0.00a | 5.12 ± 0.64a |
| F      | 1.85 ± 0.26b | 1.33 ± 0.03b | 0.88 ± 0.00b | 5.76 ± 0.64b |
| GF     | 3.57 ± 0.26b | 1.38 ± 0.03b | 2.42 ± 0.22b | 5.13 ± 0.11b |
| DB     | 0.33 ± 0.06a | 1.43 ± 0.02a | 2.86 ± 0.44a | 10.56 ± 0.32a |
| DR     | 0.46 ± 0.06b | 1.24 ± 0.03b | 2.64 ± 0.22b | 11.53 ± 0.64b |
| DA     | 0.40 ± 0.13a | 1.23 ± 0.03a | 2.36 ± 0.06a | 13.76 ± 0.32a |
| DG     | 0.33 ± 0.07a | 1.27 ± 0.02a | 4.18 ± 0.22a | 7.68 ± 0.64a |
| DF     | 1.39 ± 0.20a | 1.01 ± 0.01a | 2.31 ± 0.11a | 8.00 ± 0.32a |
| DGF    | 1.58 ± 0.26a | 1.23 ± 0.03a | 2.97 ± 0.33a | 7.36 ± 0.32a |

Values reported are means ± standard deviation of triplicate determinations. Mean values bearing different superscript roman letters are significantly (P<0.05) different from one another.

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