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Effects of Processing Methods on Proximate Composition of Decorticated Castor Seeds (*Ricinus Communis* L.)

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Effects of Processing Methods on Proximate Composition of Decorticated Castor Seeds (*Ricinus Communis* L.)

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I. Introduction

There is a tremendous increase in the rate at which livestock industry grows in the globe, which led to the continuous rise and exhaustive use of virtually all feedstuffs processed, hence inversely or overtly increasing the cost of plant and animal sources used in aquaculture feeds [1]. Over the past few decades, there has been increased exploitation of certain unconventional feeding materials as alternative protein sources to replace the costly protein materials for fish available in the market. Also, scarcity of high-quality conventional feed materials, resulting in high competition between man and farm animals [2] [3] [4].

Of the vast vegetation across the globe, castor oil seeds (*Ricinus communis* L.) is considered as one of those alternative feedstuffs, and it has been underutilized all along [5]. The plant belongs to Euro phorbiaceae, a spurge family, easy to cultivate, early matured, and grow all the year round [6]. Its species is distributed in the tropical and sub-tropical regions across the globe [7] with Brazil, China, India, and Mozambique serving as the main producers in the world [8] but India ranks its highest producer [9]. It grows well on fertile soil and tolerates not less than daytime temperatures of 20°C throughout the growing period [10]. Castor bean plant has several branches, each terminated by a spike which is 15 to 30 cm long, bearing 15 to 80 capsules [11]. A capsule contains three seeds each, which, at maturity, split to release the seeds. The seeds of the castor plant that grow in the northern states of Nigeria are classified into seven distinct varieties according to their sizes and colors [12]. However, the seeds are more classified into three groups that include large seeds (variety major), medium seeds (variety intermediate), and the small seeds (variety minor). The commonest seeds that grows in the northern parts is the minor [13].[14] reported that some castor seeds developed so far are; I. Agricultural Science Academy of Zibo in China developed; ZiboCastor No. 2; a middle-late castor with high oil content and 3750 – 5399 kg/hm2 seed yield II. ZiboCastor No. 3; a spineless, big seeded castor variety III. ZiboCastor No. 4; a high yielding castor (4500 – 6000 kg/hm2) with a lot of spikes IV. ZiboCastor No. 5; A middle-maturing, thorn less hybrid with 4500 – 6450 kg /hm2 V. ZiboCastor No. 6; Early maturing hybrid variety, yielding between 4579.5 kg/hm2 and 6750 kg/hm2 VI. ZiboCastor No. 8; A middle-maturing hybrid with about 4500 to 6000 kg/hm2.Castor Seed Cake (CSC) is available to the tune of 1.12 million t and has potential to be used as a protein supplement in animal diets because of its high crude protein and energy compared to the conventional ones but limited because of potent anti nutritional factors such as ricin, ricinine, allergen and chlorogenic acid [15] [16] [17].

Several authors had reported castor seed cake contained about 32-48% crude protein of good amino acid profile depending on the forms of detoxification adopted such as physical: boiling, soaking, autoclaving, toasting, steaming, extrusion, decortication and deoiling [18][6][19][20][21] chemical: application of calcium compounds, formaldehyde, sodium hydroxide, tannic acid, sodium chloride and lime [22][23][24] and fermentation [25].For instance, [19] reported 30.82% for crude protein, 11.42% crude fiber, 20.72% ether extract, 5.54% ash and 31.16% nitrogen-free extract.[21]also reported crude protein 23.00%, crude fiber 6.85%, carbohydrate 27.50% fat 22.67%, moisture 17.00% and ash 2.98%. However, [26] recommended the need for

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further research on the detoxification process for castor seed meal so that more economic benefit can be derived from its utilization.

Since there is an urgent need to investigate the nutritional properties of the non-conventional feedstuff to know their suitability before recommendation for animal/fish feed formulation [27], the aim of this study, to work on different methods of detoxification; each at further different levels (5x3 methods in this case), on castor seed, to find out which would be considered best in the formulation of fish feed in particular.

II. Materials and Methods

a) Study Area

The study was conducted at the fishery laboratory of the Department of Fisheries and Aquaculture, Faculty of Agricultural Science, Ekiti State University, Ado-Ekiti. Ado-Ekiti is in the Western tropical rain forest region of Nigeria, latitude 7.67^{0}N, and longitude 5.25^{0}E and at an altitude of 431m above sea level. The mean average annual rainfall of Ado-Ekiti is about 1800mm. The mean monthly temperature is about 28^{0}C, while the monthly relative humidity is about 65% [28] being in Ekiti State.

The following experiments and analysis were carried out namely

(i) Detoxification of the raw *Castor* seeds (CS) using five different treatment methods, boiling, roasting, soaking, autoclaving, and fermentation; with three different levels for each adopted. Each of the levels was replicated thrice.
(ii) Proximate analysis of both the raw and processed castor seeds was carried out thereafter.

Sample Collection/Identification: Castor seeds from dehiscence mature capsules of the plants (ZiboCastor No. 3 variety) were fetched within Ado-Ekiti metropolis, Nigeria, and used for this research. The plant capsule and seed samples were identified at the Herbarium of the Department of Plant Science and Biotechnology, Ekiti State University, Ado-Ekiti.

Sample Preparation: The collected seed samples were sorted, screened and distributed into six batches based on different treatment methods namely: (i) raw seed, (ii) boiled, (iii) toasted, (iv) soaked, (v) autoclaved, and (vi) fermented, respectively.

For each of the treatments, apart from raw seeds, three levels/ranges were worked upon to ensure proper investigation [29].

Processing of Untreated (Raw) Seeds: Two hundred (200) grams of raw castor seeds were washed, decorticated, sundried, and grounded for use of proximate analysis.

Boiling: According to [5] castor seed is best detoxified by boiling between 40-60 minutes at 100^{0}C. 2kg of castor seed samples were treated at 100^{0}C using tap water at the ratio of 1kg to 10 liters of water in a 15liter metal cooking pot for a duration of 60 minutes [30]. A portion (600g) of the original seed samples was removed from the boiling water with a sieve at 40, 50, and 60 minutes intervals, respectively, using a stopwatch while the boiling continues [29]. Samples were sun-dried separately to a constant weight; dehauled, ground, oil extracted, and packed in air-tight polythene bags against the subsequent analysis.

Toasting: Toasting time ranges for castor seed as reported by [31] and [32] between 20 and 30 minutes at 140°C, respectively. In this study, toasting was done at 20, 30 and 40 minutes using [31] method. 2kg of the raw sample of castor oil bean in a medium of sand was put in an open pan at 140°C for 40 minutes. The beans and sand were stirred continuously to avoid charring using a hand shovel. The temperature of the sand medium was monitored using a 150°C thermometer. 600g sample was removed at 20, 30, and 40 minutes intervals, then spread separately and allowed to cool on clean trays placed on concrete slabs. The processed seeds were dehauled, ground, defatted to form a cake, and then stored separately in tightly sealed labeled polythene bags.

Soaking in water: According to [19], the minimum and maximum duration of soaking CS ranges between 48-96 hours. In this study soaking of castor seed was carried out at 48, 72, and 96 hours. 2kg of Raw *RC* samples was put into a bowl containing tap water at the room temperature (30 ± 2^{0}C) in seed to water ratio of 1:10(w/v) at the rate of 5kg to 10litres [30]. The samples were removed at the rate of 600g with a sieve at 48, 72, and 96 hours respectively and then spread separately on clean trays to sundry. Dehauling, grinding, and oil extraction to enhance cake formation followed accordingly.

Autoclaving: According to [33], the minimum and maximum minutes of autoclaving for castor seed range between 20-40 minutes. In this study, autoclaving of CS at 121^{0}C was carried out for 20, 30, and 40 minutes to examine the best level. 2kg raw seeds sample were parboiled for 2 minutes in water at 60^{0}C to ease dehulling. 600g was removed at each time interval. Samples were sun-dried separately to a constant weight, dehauled, and oil extracted. The samples were then packed in air-tight polythene bags against the subsequent proximate analysis.

Fermentation: According to [21], the minimum and maximum duration of fermentation of CS range between 48-96 hours. This study fermented castor seed at 48, 72, and 96 hours. 2kg of raw castor seed sample was used for the fermentation technique. Slightly warm water (60^{0}C) was poured on the seeds and then covered in an air-tight container [34] to allow natural fermentation to take place; 600g was collected at the expiration of each time (48, 76, and 96 hours) interval. Each of the samples

was sun-dried separately to a constant weight, dehauled, oil extracted, and then packed in air-tight polythene bags against the subsequent analysis.

Chemical Analysis: The properly labeled processed seeds for all the treatments (16), each of which was replicated thrice, were taken to the Laboratory of the Department of Fisheries and Aquaculture, Ekiti State University, for proximate analysis.

Determination of nitrogen/crude protein by Kjeldahl method [35]: The principle of this method is to digest the organic matter with sulphuric acid in the presence of a catalyst to render the reaction alkaline, and then distill and titrate the liberated ammonia.

Determination of Crude Fiber [35]: This involves sequential digestion of the sample with dilute acid and alkaline solution. The residue was ignited to obtain crude fiber.

Determinations of nitrogen-free extract (NFE) [35]: The total carbohydrate content was determined by the difference method. The sum of the percentage moisture, % ash, % crude lipid, % crude protein, and % crude fiber was subtracted from 100. NFE= 100- (ash + crude lipid + crude protein + crude fiber).

Determination of ash content [35]: The ash content was determined from the loss in weight that occurred during igniting the sample at 550°C in muffle furnace, which was enough to allow all organic matter to burn off, hence the decomposition of the ash constituent occured.

Determination of moisture content and Dry Matter [35]: This is based on the difference between the net weight and the weight after drying. This also determines the weight of dry matter. A clean crucible was dried to a constant weight in an air oven at 110°C, cooled in a dessicator and weighed (W1). 2g of finely pulverised sample was weighed in the crucible and then re-weighed (W2). The crucible and its content were dried in an oven to a constant weight (W3). The percentage moisture was calculated thus: % Moisture content = {(W2-W3)/ (W2-W1)} x 100.

Determination of crude lipid content [35]: This is the continuous extraction of fat content from the sample using suitable solvent, e.g. petroleum ether in Soxhlet, since the non-polar component of the sample is easily extracted into the organic substance (ether).

III. Statistical Analysis

Data obtained were subjected to a one-way analysis of variance (ANOVA) to determine the significance of the variations between parameters was examined at ($P<0.05$). Means obtained were segregated using Duncan's multiple range tests (DMRT) with the aid of SPSS version 20

IV. Results

The proximate composition of the autoclaved castor seed at 0, 20, 30, and 40 minutes time intervals are shown in Table 1. For the moisture contents, significantly different ($p>0.05$) were obtained in all the treatments, including the control. However, the sample autoclaved at 20 minutes was highest (5.53±0.03), while the 0 minute recorded the least value (4.85±0.03). In the same vein, the crude protein, fats, ash, crude fiber, and nitrogen-free extract (NFE) contents are significantly different ($p>0.05$) among the various levels of autoclaving. Crude protein and fats were highest in raw (control) (38.29±0.11, 28.65±0.15) and lowest at 20 minutes (5.13±0.07, 16.53±0.13) respectively. Ash was highest at 20 minutes treatment (5.47±0.02) and lowest in 30 minutes treatment (4.60±0.03). The crude fiber was highest in castor seeds autoclaved for 20 minutes (3.53±0.08) and least recorded at 0 minutes (2.08±0.05). NFE was recorded highest at 20 minutes autoclaved (48.29±0.23) and lowest in control (16.50±0.14).

Table 1: Percentage proximate composition of autoclaved Castor seed cake (CSC) at different time intervals

	Parameter	Moisture	Protein	Fats	Ash	Crude Fiber	NFE
Treatments	$RCSC_{00}$ (Control) (00 min)	4.85 ± 0.03^{a}	38.29 ± 0.11^{d}	28.65 ± 0.15^{d}	4.79 ± 0.02^{b}	2.08 ± 0.05^{a}	16.50 ± 0.14^{a}
	$ACSC_{20}$ (20 min)	5.53 ± 0.03^{d}	15.13 ± 0.07^{a}	16.53 ± 0.13^{a}	5.47 ± 0.02^{d}	3.53 ± 0.08^{d}	48.29 ± 0.23^{d}
	$ACSC_{30}$ (30 minutes)	5.29 ± 0.01^{b}	36.25 ± 0.13^{c}	22.76 ± 0.16^{b}	4.60 ± 0.03^{a}	2.65 ± 0.09^{b}	23.18 ± 0.19^{b}
	$ACSC_{40}$ (40 min)	5.44 ± 0.02^{c}	21.43 ± 0.18^{b}	25.63 ± 0.23^{c}	5.20 ± 0.02^{c}	3.23 ± 0.03^{c}	32.65 ± 0.47^{c}

Values shown are means ± standard error. Those with different letters along the same column are significantly different at $p<0.05$.

The proximate composition of the boiled castor seed at 0, 20, 30, and 40 minutes time intervals are shown in Table 2. The mean values recorded in terms of moisture, crude protein, fats, crude, ash, fiber, and NFE contents are significantly different ($p>0.05$) from one another. However, the mean values for moisture, crude

protein, fats, and ash were highest in control (4.85±0.05, 38.29±0.11, 28.65±0.15 and 4.79±0.02) but lowest in 40 minutes boiled (4.15±0.00), 60 minutes boiled (33.97±0.07); 50 minutes boiled (22.32±0.18 and 3.83±0.05) respectively. Mean value for crude fiber was highest in 60 minutes boiled CSC (2.71±0.01) and lowest in control, 0 minutes (2.08±0.05). NFE mean value was highest in 50 minutes, boiled CSC (31.19±0.23). and lowest in control (16.500.14).

Table 2: Percentage proximate composition of boiled Castor seed cake (CSC) at different time intervals

	Parameter	Moisture	Protein	Fats	Ash	Crude Fiber	NFE
Treatments	$RCSC_{00}$ (Control) (00 min)	4.85±0.03^{d}	38.29±0.11^{d}	28.65±0.15^{b}	4.79±0.02^{d}	2.08±0.05^{a}	16.50±0.14^{a}
	$ACSC_{20}$ (20 min)	4.15±0.0^{a}	36.98±0.16^{c}	24.19±0.01^{b}	3.86±0.04^{b}	2.53±0.03^{b}	28.30±0.16^{b}
	$ACSC_{30}$ (30 minutes)	4.23±0.0^{b}	35.79±0.01^{b}	22.32±0.18^{a}	3.83±0.05^{a}	2.65±0.01^{c}	31.19±0.23^{d}
	$ACSC_{40}$ (40 min)	4.38±0.0.02^{c}	33.97±0.07^{a}	26.40±0.20^{c}	3.88±0.02^{c}	2.71±0.01^{d}	28.67±0.11^{c}

Values shown are means ± standard error. Those with different letters along the same column are significantly different at p<0.05.

The proximate composition of the fermented castor seed at 0, 48, 72, and 96hours time intervals are shown in Table 3. The mean values recorded in terms of moisture, crude protein, fats, crude, ash, fiber, and NFE contents are significantly different (p>0.05) from one another. However, the mean values of moisture, crude protein, and ash were highest in control (4.85±0.03, 38.29±0.11 and 4.79±0.02) but lowest in 48 hours fermented CSC (4.110.01, 29.51±0.11 and 3.33±0.03) respectively. The fats and crude fiber mean values were highest in 96 hours fermented CSC (32.60±0.20 and 2.63±0.03) and lowest in control CSC (28.65±0.15 and 2.08±0.05) respectively. The NFE mean value was highest in 48 hours fermented CSC (30.94±0.23), and lowest in raw CSC (16.50±0.14).

Table 3: Percentage proximate composition of fermented Castor seed at different time intervals

	Parameter	Moisture	Protein	Fats	Ash	Crude Fiber	NFE
Treatments	$RCSC_{00}$ (Control) (00 min)	4.85±0.03^{d}	38.29±0.11^{d}	28.65±0.15^{b}	4.79±0.02^{d}	2.08±0.05^{a}	16.50±0.14^{a}
	$ACSC_{20}$ (20 min)	4.11±0.01^{a}	29.51±0.11^{a}	29.65±0.15^{b}	3.33±0.03^{a}	2.48±0.02^{b}	30.94±0.23^{d}
	$ACSC_{30}$ (30 minutes)	4.23±0.01^{b}	31.50±0.10^{b}	30.25±0.15^{c}	3.43±0.02^{b}	2.55±0.01^{c}	28.05±0.29^{c}
	$ACSC_{40}$ (40 min)	4.27±0.01^{c}	33.23±0.03^{c}	32.60±0.20^{d}	3.60±0.01^{c}	2.63±0.03^{d}	23.68±0.21^{b}

Values shown are means ± standard error. Those with different letters along the same column are significantly different at p<0.05.

The proximate composition of the soaked castor seed at 0, 48, 72 and, 96 hours time intervals are shown in Table 4. The mean values recorded in terms of moisture, crude protein, fats, crude, ash, fiber, and NFE contents are significantly different (p>0.05) from one another. However, the mean value for moisture was highest in control (4.85±0.03), diminishes down to 3.83±0.04 while the soaking duration lasted. 38.29±0.11. The protein content of the CSC sample reduced after 48 hours soaking (32.67±0.11); further at 72 hours (30.46±10), but increased to 34.11±0.03 after 96 hours. The fats content increased after subjecting it to soaking for 48 hours (30.43±0.15) but reduced along with the trend of the soaking period. Ash content was lessened irregularly from 4.70±0.02 in the raw sample to 3.91±0.03, 3.95±0.02, and 3.70±0.01 in the soaked seeds (48, 72, and 96 hours) respectively. The mean values of crude fiber increased with an increase in the length of soaking periods. NFE mean value increased at 48 hours soaking (26.28±0.23) and then increased further at 72 hours (30.00±0.29) but declined to 26.60±0.21 at 96 hours soaking.

Table 4: Percentage proximate composition of soaked Castor seed at different time intervals

	Parameter	Moisture	Protein	Fats	Ash	Crude Fiber	NFE
Treatments	$RCSC_{00}$ (Control) (00 min)	4.85±0.03[d]	38.29±0.11[d]	28.65±0.15[b]	4.79±0.02[d]	2.08±0.05[a]	16.50±0.14[a]
	$ACSC_{20}$ (20 min)	4.19±0.01[a]	32.67±0.11[b]	30.43±0.15[d]	3.91±0.03[b]	2.53±0.02[b]	26.28±0.23[b]
	$ACSC_{30}$ (30 minutes)	4.34±0.01[b]	30.46±0.10[a]	28.88±0.15[c]	3.95±0.02[c]	2.62±0.01[c]	30.00±0.29[c]
	$ACSC_{40}$ (40 min)	4.44±0.01[c]	34.11±0.03[c]	28.52±0.20[a]	3.70±0.01[a]	2.64±0.03[d]	26.60±0.21[b]

Values shown are means ± standard error. Those with different letters along the same column are significantly different at $p<0.05$.

The proximate composition of the toasted castor seed at 0, 48, 72, and 96 hours time intervals are shown in Table 5. The mean values recorded in terms of moisture, crude protein, fats, crude, ash, fiber, and NFE contents are significantly different ($p>0.05$) from one another. However, the mean value of moisture was highest in control (4.85±0.03), diminishes down to 3.83±0.04 while the toasting duration lasted. The protein content of the CSC sample reduced after 20 minutes toasting (33.08±0.73); further at 30 minutes (30.66±04), and 40 minutes (28.55±0.35). The fats content reduced after subjecting it to toasting for 20 minutes 26.17±0.07), and further at 30 minutes (24.50±0.10), but increased to 28.25±0.15 at 40 minutes toasting period. Ash content reduced from 4.79±0.02 in the raw sample to 4.32±0.02 when subjected to 20 minutes toasting. The values, however, increased up to 4.77±0.03 as the toasting period lasted. The mean values of crude fiber increased with an increase in the toasting periods, from 2.08±0.05 in raw samples to 2.33±0.03 and 2.43±0.01 at 20 and 30 minutes, respectively. It, however, declined at 40 minutes toasting level (2.42±0.02). NFE mean value increased from 16.50±0.14 of the raw sample to 29.99±0.64 and 33.99±0.12at 20 and 30 minutes toasting levels, respectively. The value declined to 32.19±0.58 at 40 minutes toasting level.

Table 5: Percentage proximate composition of toasted Castor seed at different time intervals

	Parameter	Moisture	Protein	Fats	Ash	Crude Fiber	NFE
Treatments	$RCSC_{00}$ (Control) (00 min)	4.85±0.03[d]	38.29±0.11[d]	28.65±0.15[d]	4.79±0.02[d]	2.08±0.05[a]	16.50±0.14[a]
	$ACSC_{20}$ (20 min)	4.13±0.03[c]	33.08±0.73[c]	26.17±0.07[b]	4.32±0.02[a]	2.33±0.03[b]	29.99±0.64[b]
	$ACSC_{30}$ (30 minutes)	4.02±0.01[b]	30.66±0.04[b]	24.50±0.10[a]	4.50±0.02[b]	2.43±0.01[d]	33.99±0.12[d]
	$ACSC_{40}$ (40 min)	3.83±0.04[a]	28.55±0.35[a]	28.25±0.15[c]	4.77±0.03[c]	2.42±0.02[c]	32.19±0.58[c]

Values shown are means ± standard error. Those with different letters along the same column are significantly different at $p<0.05$.

V. Discussion

a) Protein content

The crude protein (CP) values recorded in the processed castor seeds in this study were significantly different ($p>0.05$) and lower than the control. The protein content reported in this work (38.29±0.11) is higher than that reported by [36] [19] [21], 33.09%, 30.82% and 23.00% respectively, in raw undecorticated castor seeds. The observed differences may be a related to differences in geographical distribution and variety [18]. In this study, the boiled seeds gave the highest mean value (36.98±0.16) of crude protein at 40 minutes duration of boiling, while autoclaving for 20 minutes gave the least (15.13±0.07) of crude protein. All the processing methods reduced the protein content of castor seed. This trend corroborates the reports of [37] [38] [21] [39] [19] who reported reduction effect of autoclaving, boiling, fermentation, soaking, and toasting on the crude protein of castor seeds and walnuts [40]. This result may be related to the effect of temperature during autoclaving, boiling, and toasting periods [37] [38] [40] then hydrolysis and microbial activities during

the fermenting and soaking periods [41].The least value of CP obtained in autoclaved castor seeds at 20 minutes in this work corroborates with [42] report, which indicated low protein value in *A. nilotica* make it a bad source of proteins. However, the mean values of CP obtained in all (except autoclaving at 20 and 40 minutes periods) the processed methods adopted fell within the acceptable percentage [43][5][32] of 28.55±0.35 and 36.98±0.16; an indication that boiling, fermenting, soaking, and toasting can be recommended as acceptable treatments for castor seeds in fish feed formulation.

b) Crude fiber content

Crude fiber (CF) values in all the treatments are significantly different($p < 0.05$) from one another. It is highest in castor seed sample autoclaved at 20 minutes ($ACSC_{20}$), 3.53±0.08, and least in control sample 2.08±0.05. The low values recorded in this study were an improvement over 4.71% and 6.42% reported by [44][21],respectively. This disparity could be as a result of variety, geographical location, and probably processing techniques. The reduction in CF values among the various treatments is due to softening and subsequent dehauling of the seeds [38].Since high CF affect digestibility, dry matter, and pellet durability [45], dehauling castor seed, as done in this study, should be used when using the seeds in fish feed. [46] reported low CF enhances digestibility, but a high level can lead to intestinal irritation, lowered digestibility, and decreased nutrient absorption, hence not appropriate for consumption [47]. A low CF diet prevents constipation and reduces cholesterol levels in the blood [48].

c) Lipids/Fats content

Lipid provides the body with maximum energy and lends a pleasant taste and texture in food [36], regulates the action of hormones, and facilitates transmission of the nerve impulse [49]. Hence its estimation is considered among the vital factors for nutritional evaluation of any material [50]. The mean value of lipid recorded was highest(32.60±0.20) in castor seeds, fermented for 96 hours ($FCSC_{96}$),and least (16.53±0.13) in seeds autoclaved at 20 minutes duration.This result is in contrast with the values, 6.57 ± 0.23, 5.13 ± 0.19, and 4.24 ± 0.11 reported for *Morus alba* L., *Morus nigra* L. and *Morus rubra* L. respectively by [51]. The lowest value obtained in the autoclaved seed could be attributed to the denaturing effect of heat and loss of volatile essential fatty acids. The concentration of lipid reduced progressively from raw to autoclaved, boiled and toasted, but increased with fermentation and soaking. This result is in tandem with the report of [52] [53], who obtained a decrease in lipids with increasing duration of boiling and toasting in *Bauhinia* and *Parkia* seed respectively. The observation could be attributed to solubilization and leaching of oil in the process of treatment. This observation is in tandem with that of [54][19], who worked on *Canavalia ensiformis* and castor seeds, respectively. The values obtained in this work are near the range of conventional plant materials such as Soybeans. [36] reported lipid content in Bauhinia was 28.70%, a value that compared with other oil seeds like Soya bean (27%)[55]. [56] reported a plant-based food that provides more than 12 % of its caloric value from protein is considered as a good source of proteins. High lipid content, if not defatted or antioxidant added to seed, can cause rancidity to feed [43].

d) Ash content

In this study, all the values in various levels in each treatment are significantly different ($p > 0.05$). In each of all the levels, there was a reduction in the ash content of castor seed from 4.79±0.02 except in autoclaving at 20 and 40 minutes levels where the values increased above the control value, 5.47±0.02 and 5.20±0.02 respectively. Hence, the highest Ash value (5.47±0.02) was obtained in autoclaved seed sample ($ACSC_{20}$), while the least mean value was recorded in the fermented seed sample at 48 hours ($FCSC_{48}$), 3.33±0.03.[42] reported a similar ash value of 5.0±0.01% in the proximate profile of *Acacia nilotica*. The substantial reduction of most of these treatments corroborates the reports of [57] [19] [58]. This might be due to the effect dehauling had on the seeds, and the leaching of its elements along with the treatments. High ash content recorded in autoclaving indicates the presence of an heavy amount of inorganic nutrients in plant material [59]. The least ash value of the fermented seed makes it stands a better chance as energy source among other treatments since ash does not involve in total digestible nutrients (TDN) [60].

e) NFE content

The nitrogen-free extra (NFE) increased at all the levels of processing used for the castor seeds. Whereas the mean values of NFE recorded range between 23.18±0.19 to 33.99±0.12, while, the raw value was 16.50±0.14. However, all the treatments are significantly different ($p < 0.05$). The highest value was in toasting treatment at 30 minutes level ($TCSC_{30}$). This result corroborates with the work of [52], where, the mean value of 27.45% was recorded against roasted Bauhinia seeds. The trend of NFE values obtained from boiled and soaked castor seeds in this work are similar to values reported by [19]. Although toasting at 30 minutes period was highest, boiling at 40 minutes ($BCSC_{40}$) is considered better because of its corresponding highest protein value. This is an indication that boiling at 40 minutes will enhance a high value of TDN [60].

f) Moisture content

In this study, all the moisture content values among various levels of treatments are significantly different ($p>0.05$). The disparity could be due to experimental error and processing techniques. The highest value obtained was 5.53 ± 0.03 in autoclaved castor seeds at 20 minutes ($ACSC_{20}$) and least (3.83 ± 0.04) in seeds toasted at 40 minutes ($TCSC_{40}$). Apart from autoclaving treatment levels, there was a significant reduction in the levels of moisture in all other treatments (boiling, fermenting, soaking, and toasting) compared to the value (4.85 ± 0.03) obtained in the control sample ($RCSC_{00}$). The decrease in moisture content recorded was in contrast with the report of [21], which increased drastically up to between 17.00% and 31.00% for castor seeds subjected to levels of fermentation. The moisture contents of the processed castor seed meals were generally low. This report agreed with [61], who reported low moisture below 15% content is required as safe storage limit for plant food materials.

VI. Conclusion

Based on the results of this study, the boiled castor seed gave the best results in terms of maximum levels of proximate components compared to autoclaving, fermenting, soaking, and toasting. The high crude protein value (36.98%) and low crude fiber (2.53%), fats (24.19%), and ash (3.86%) contents recorded in the 40 minutes boiled seed ($BCSC_{40}$) in this study make it the best boiling level for treatment of castor seed. The results also showed that castor seed has appreciable nutritional potential and can be a better source and supplement for fish feed formulation.

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