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Physicochemical Properties and Lipid Profile of Two Varieties of Raw and Parboiled Cameroonian Ndop Rice (Oryza sativa) Bran Oil: Effect of Oven Drying of the Bran on the Oil Chemical Properties and Oil Yields

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Abstract

Rice (*Oryza sativa*) is the world's single most important crop and a primary food source for over half of the world's population. Before consumption, rice is usually milled and sometimes parboiled before milling. Rice bran which is a by-product of rice milling, has been reckoned as a potential source of edible oil. This oil is widely used in pharmaceutical, food and chemical industries due to its unique properties and high medicinal value. In this study, oil was extracted from two varieties (Tox and Nerika) of raw and parboiled Ndop rice bran and characterized for oil yield and quality indices. The quality indices of the extracted oil (acid value, iodine value, peroxide value, saponification value and thiobarbituric acid value) were determined using French Norm for fat and oil (AFNOR). Results revealed that bran from Tox variety produced more oil (12.75-13.75% v/w) than Nerika (5-6% v/w). The Tox parboiled variety of Ndop rice bran yielded the highest percentage (13.75%v/w) of oil. In both varieties, parboiling slightly increased the percentage oil yield. The free fatty acid (0.42 – 0.70%), iodine value (95.40 – 101.30gI_2/100g), peroxide value (7.35 – 2.172meq/kg) and thiobarbituric acid value (0.023 – 0.040) were within the acceptable ranges of Codex Alimantarius. Saponification value of oil samples ranged between 144.93 to 168.85mg/g of oils. Parboiling improved the quality of Ndop rice bran oil by decreasing the acid, peroxide and thiobarbituric acid values, but had no significant effect on the iodine value. The fatty acid composition of the oils from the two varieties of rice bran oil shown that rice bran oil is an unsaturated oil, with unsaturated fatty constituents ranging between 73.44 and 74.33% and the saturated counterparts between 25.66 and 27.17%. Rice Bran Oils were rich in monounsaturated fatty acids 42.62 - 43.44%, and also polyunsaturated fatty acids between 30.7 and 30.88%. The saturated, mono-unsaturated and polyunsaturated fatty acids that were more predominant in the oil were palmitic, oleic and linoleic acids respectively. For the n-3 PUFA family, the highest proportions were found in ToxNon Parboiled and Nerika Non Parboiled (30.88% and 4.37% respectively. The levels PUFA/SFA obtained here were greater than 0.45. Artherogenic index (AI) is proposed to evaluate risky factors that are implicated in coronary heart disease development ; It was < 0.4 in the investigated rice bran oils, owing to the high n-6 PUFA contents and low n-3 ratios. Oven drying of the bran provoked changes on the rice oil. Ndop rice bran is therefore a good source of edible oil whose quality can be improved by parboiling and oven drying.

Keywords: *Rice Bran, Oryza sativa, Oil, Lipid Profile, Fatty Acids, Parboiled, Polyunsaturated Fatty Acids.*

1. Introduction

Rice (Oryza sativa) is the world's single most important crop and a primary food source for over half of the world's population [1]. More than 500 million metric tons of milled rice is produced per year worldwide, constituting more than a quarter of all cereal grains [2]. Rice bran is a huge agricultural waste of rice polishing industry, produced during milling of brown rice.

Rice processing covers the operations from harvesting to the production of graded and polished white rice. It may be parboiled before milling. Rice parboiling is a hydrothermal process consisting of soaking, heating and drying operations

which modifies the qualitative and processing behaviour of rice [3, 4]. During soaking, water migrates into the rice kernel by diffusion [4] and subsequent heating leads to irreversible swelling and fusion of starch granules. The starch granules are gelatinized and retrograded, and during drying, the amylose molecules re-associate with each other and form a tightly packed structure [6]. Rice parboiling can be done on a small scale (local), making use of devices such as drums and boilers which use direct and indirect heating respectively, which consume all different amounts of energy [7,8]. Agri-residues are the main sources of energy for local parboiling, especially the residues of rice processing industries. However other energy sources such as wood are also used. Sun-drying is a common practice in local parboiling processes. Water for the process is obtained from a nearby pond, river, lake or tube-well. Parboiling treatment induces various physicochemical changes in paddy rice which play an important role in the subsequent storage, milling, cooking and eating qualities. Although rice parboiling is known to have a number of advantages, it requires more energy, water and time during processing and cooking than untreated rice. The parboiling treatment gelatinizes the rice starch, improves the hardness of the rice upon drying, minimizes breakage during milling, and thus increases the yield after milling. Parboiling also prevents the proliferation of fungus and insects [9, 10].

Parboiling of paddy increases the oil yield of the rice bran. According to Amarasinghe *et al*. [11], this may be due to the fact that parboiling releases the oil in the grain and results in outward migration of the oil. On the contrary, investigations by Anil Kumar *et al*. [12] show that tocopherols are completely lost due to parboiling of paddy. The process of parboiling however has some disadvantages like needing more energy, more water and more processing and cooking time. In addition, it has undesirable effects such as a dark colour, harder product [10,13] and a peculiar smell and taste. Over-parboiling results in over-opening of the husk components followed by bulging out of the endosperm; which initiates surface scouring during milling and the resultant ground particles being lost into the husk and bran.

Although, it has been recognized as an excellent source of vitamins and minerals, it is underutilized as human food. In addition to its many uses, rice bran has been reckoned as a potential source of edible oil [14]. This oil is widely used in pharmaceutical, food and chemical industries due to its unique properties and high medicinal value (Amarasinghe *et al.* [11]. Rice bran is the most important by-product of rice milling. It is a valuable source of edible oil in most rice producing countries. Rice bran oil is used in baby food, biscuit, poultry, fish and farm animal feeds. The storage of rice bran without 'heat processing will result in hydrolysis and auto-oxidation of lipids, and to its decreased physicochemical, organoleptic and nutritional quality. Rice bran is rich in carbohydrates, free amino acids, lipids and different enzymes. The enzymes have destructive effects on the quality of rice bran components. Heat processing is an effective method to reduce the microbial and enzymatic activity of bran [15, 16].

In Cameroon, according to Ministry of Agriculture and Rural Development in 2020 about 140.170 tons of rice and a great amount of rice bran is produced every year, which is either wasted or used as animal feed. The use of rice bran as feedstock for the production of oil instead of being regarded as a waste would have more positive impact on food supplies and food security than when edible crops like Soya beans and corn are used. This is because it is a by-product and does not require extra land, labour and other farm inputs for its planting. Besides this, the amount of available edible rice will not be reduced. Agro-industry yields ample quantity of several by-products with considerable importance, but these by-products are usually under-utilized, may serve as animal feed or rejected as waste, hence their true potential is not harnessed [17]. Rice bran is one of these agro-industrial by-products and is an important product of rice milling industry with a global potential of 29.3 tons annually [17]. In Cameroon, a great quantity of this rice bran is produced annually, but its true potential not harnessed, while other countries like Thailand, China and India use the rice bran they produce to make oil [18]. Cameroon has a good source of raw material for a rice bran oil industry, which will generate employment, and produce rice bran oil as intermediate raw material for food and pharmaceutical industries. Several works of research have been done on rice bran oil in different countries, but not yet in Cameroon. The objective of this study was therefore to test for the physicochemical properties of two varieties of raw and parboiled Ndop rice bran oil.

2. 2. Materials and Methods

2.1 Sampling area, sample collection and processing

Raw and parboiled rice bran samples were collected from rice mills in Ndop, North West Region, Cameroon. Ndop is the headquarters of the Ngoketunjia Division. Geographical coordinates of Ndop are 6˚ 0' 0" North and 10˚ 25' 0" East. The

samples were then carried to the life Science Laboratory of the University of Buea, South West Region, Cameroon where processing and analysis were carried out on it. The specific rice bran samples obtained were "Nerica" parboiled and unparboiled, and "Tox" parboiled and unparboiled. The "Nerica" variety was obtained from a local rice mill in Ndop, while the "Tox" variety was obtained from the UNVDA (Upper Nun Valley Development Authority) rice production unit. The rice bran was sieved with a 1mm sieve to remove foreign materials, broken rice grains and hull particles. After sieving, it was placed in a refrigerator at 0˚C for 24 hours to stabilize it in order to reduce enzymatic activity that can make the bran rancid [19, 20]. Figure 1 shows the sieved raw rice bran (A) and the parboiled rice bran (B) collected from the rice mills.

Fig. 1 Sieved rice bran: (A) Non parboiled Ndop rice bran. (B) Tox Parboiled Ndop rice bran (C) Nerica Parboiled rice bran.

2.2 Parboiling

The parboiling process was carried out in modern equipment at the UNVDA technical sector for rice production, and took 48 hours to be completed. The silo (a huge metal tank), was filled with paddy rice. The paddy rice was then transferred into another tank containing hot water and left there to soak over the night (12 hours). At the end of 12 hours, the paddy rice was then cooked at a temperature of 100˚C for 3 hours, after which the water was drained. The paddy rice was then dried using electricity and gas for 8 hours to a moisture content of 14% (UNVDA production unit).
The top of this paragraph illustrates a sub-subheading.

2.3 Oven drying

The two rice bran varieties and their parboiled bran were divided into six portions and each portion was oven dried using and electrical conventional oven drier at a constant temperature of 50°C for 24 hours. For the oil yields, samples were oven-dried at the same temperature for 6 hours, 12 hours, 18 hours, 24 hours and 30 hours and one sample was not dried and this served as 0-hour sample (control sample). This gave a total of 24 samples (6 × 2 varieties of non-parboiled, plus 6 × 2 varieties of parboiled) from which yields were evaluated. Each sample was then ground with an electric blender. Each dried refined bran was then stored in an air-tight plastic for the oil extraction. The overall flow chart of the process is summarised on Figure 2.

2.4 Extraction of rice bran oil

Oil from the rice bran was extracted by marceration using hexane as a solvent. 600 ml of hexane was added to 200g of rice bran. Upon maceration, the mixture was shaken occasionally every 15 minutes and was kept for 24 hours. The homogenate was filtered and concentrated under vacuum using rotary vapour (40°C); after which the supernatant was collected and evaporated to obtain the solvent-free oil [21]. The resulting extract were placed in an oven at 35°C for 2 days to remove residual solvent, weighed and stored at 4 °C until used [22].

2.5 Percentage (v/w) oil yield

The percentage oil yield of each rice bran sample was determined by measuring the volume of the oil that the bran yielded after maceration using the following formula: % oil Yield = (volume of oil)/(weight of bran)×100

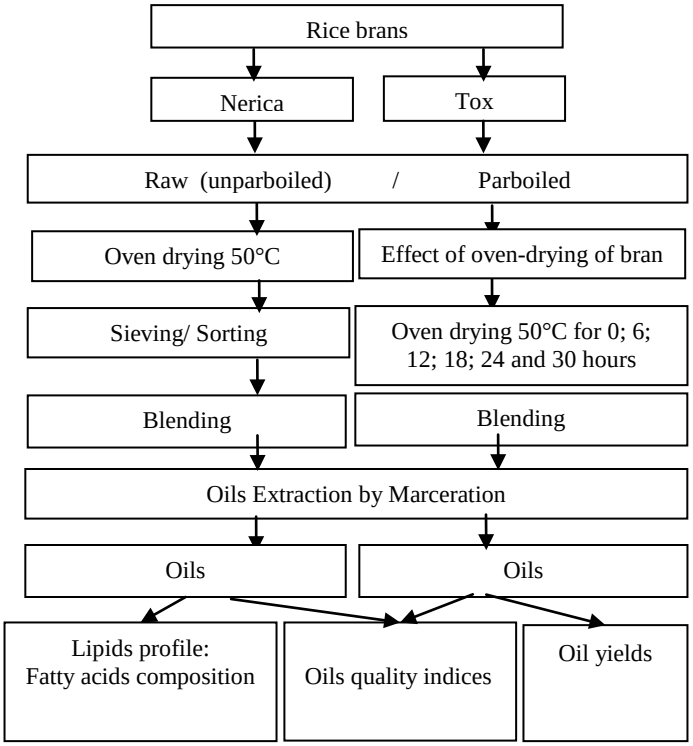

Fig. 2 Work flow chart of the process.

2.6 Characterization of the rice bran oil

2.6.1 Chemical properties of oils: Determination of oil quality indices

Acid value (expressed as % free fatty acids (% FFA)), iodine (IV), peroxide value (PV), saponification value (SV) and thiobarbituric acid value (TBAR-V) value were assessed on oils extracted as recommended by standard NFT60-204 of the French Association for Standardization [23].

2.6.2 Fatty acid composition

Fatty acid composition of the oil was investigated after conversion of their Fatty Acid Methyl esters (FAME) by using boron trifuoride-methanol method. The lipids were saponified and esterified for fatty acids analysis by the method of Metcalfe et al. [24]. The fatty acids methyl esters (FAMEs) were analysed on a Hewlett-Packard (HP) 5880 Gas Chromatograph (GC) with a Flame Ionisation Detector (FID). The esters were separated on a 50 m × 0.20 mm I.D. wall-coated open tubular fused silica capillary column coated with Carbowax 20 M. Column injector and detector temperatures were 200 and 300°C, respectively. Carrier gas was helium; split ratio was 100:1. Identification was achieved by comparison to retention times of authentic standards. The Atherogenic index = (C1 2 : 0 + 4 × C1 4 : 0 + C16 : 0) / [∑ M UF A + ∑ (n - 6) + ∑ (n - 3)] was calculated from the fatty acids composition.

2.7 Statistical Analysis

The results were analyzed with the R software, using the ANOVA and Turkey honest Significant Differences (Turkey HSD) computation program. The means of the acid value, saponification value, peroxide value, iodine value and thiobarbituric acid value for the triplicate samples were calculated using Microsoft Excel. Also, the significant differences of the oil yields between the different varieties of rice bran (raw and parboiled) were determined at 5% level of significance. The significant

differences of the five parameters under study between the different RBO varieties (raw and parboiled) as well as the significant differences of the parameters under study between the raw and parboiled RBO of each variety was determined.

3. Results and Discussion

3.1 Chemical analysis of rice bran oil

3.1.1 Free fatty acids

Table 1 presents the chemical content of oils extracted from Parboiled and non-parboiled rice bran (Tox and Nerika varieties). Oils from parboiled rice recorded significantly ($P<0.05$) lower results for free fatty acids. Parboiling increased the oil acidity from 0.48 to 0.70% and from 0.42 to 0.58 % respectively for Tox and Nerika varieties indicating that parboiling has an effect on fatty acid by inactivating endogenous lipases. Acid value indicates the amount of free fatty acids (FFA) present in oil [25]. It is a good indicator of oil degradation caused by hydrolysis. The acid value of Ndop rice bran oil was between the acceptable range (≤1.5% oleic acid) of WHO and Codex Alemantarius for edible oils [26]. According to Amarasinghe et al. [11] rice bran are unstable during storage. This instability is attributed to the activity of the enzyme lipase present in the outer layers of the rice kernel which is the primary factor responsible for the hydrolysis of triglycerides in the rice bran into glycerol and free fatty acids.

The free fatty acids formed bring about a reduction in pH, rancid flavour and soapy taste which render the rice bran unsuitable for human consumption [27, 28].An increase in the free fatty acid was also observed by Ramezanzadeh et al. [29] within hours and reached 5–7% within the first 24 h and 40% within 15 days [30]. Rice bran oils with FFA >5% are considered unfit for human consumption [31]. Ndop rice bran oil can therefore be stored for long since the free fatty acid is much lower than 10. Ten instead of 1.5% of codex alimentarius because it contain both lipophilic antioxidants (tocopherols, tocotrienols and γ-oryzanol) and phenolics [32, 33]. Moreover, Ndop rice bran oil has a better acid value than commercially available rice bran oil, olive oil and coconut oil in Andhara Pradesh state in India, as analyzed and reported by Madhavi and Soroja [34].

To prevent rice bran from becoming rancid, lipase activity must be arrested by some stabilization process immediately after the milling process [19]. Parboiling is one of the techniques among stabilization methods namely; thermal, chemical stabilization and refrigeration [35]. Hydrothermal treatments [36], steaming [37, 38], extrusion [39, 40], microwave heating [41], ohmic heating [42, 43] and infrared radiations [28] were also reported to have such actions. The stabilization techniques that best control lipase activity are steaming, hot air drying, chemical stabilization and refrigeration, with steaming being the most effective [11]. The process also destroys the fungi, bacteria and insect infestations, hence enhancing the shelf life of rice bran [44].

3.1.2 Iodine value

Iodine values are an indication of the degree of unsaturation of oils. The Iodine value for the rice bran oil in this study was found to be range between 95 to 102 g I_2/ 100 g oil and par-boiling decreased the iodine value of the Tox variety but this reduction of iodine value was not significant for Nerika variety. The iodine values obtained here are in the range of 85 to 105 g I2/ 100 g oil value for crude rice bran oil and 90 to 105 g I2/ 100 g oil for refined rice bran oil reported by Ramachandran (2001). The progressive reduction in iodine value usually could be attributed to lipid oxidation [46]. The higher the Iodine value, the higher the degree of unsaturation. When Iodine value is lower, it means that the double bond of the polyunsaturated fatty acid (PUFA) of the oil had been attacked and oxidation of the oil had taken place. Thus, there is progressive reduction of the nutritional value of the oil. Oils rich in unsaturated fatty acids have been reported to reduce heart diseases associated with cholesterol [47]. Although, Falade et al. [48] explained that high Iodine value also has its own disadvantages; for instance, the oils will be more susceptible to oxidative deterioration thereby making them difficult to store.

3.1.3 Peroxide value

The peroxide value was lowest in non-parboiled and highest in Nerika parboiled. Peroxide value is used as an indicator for oil rancidity or freshness. It is a measure of concentration of peroxides and hydro-peroxides formed in the initial stages

of lipid oxidation [26]. The higher the peroxide value, the more rancid the oil is. The peroxide value is used as an indicator of deterioration of oils.

Table 1: Oil yield and chemical content of oil extracted from Tox parboiled, Tox non-parboiled, Nerika parboiled and Nerika non-parboiled rice brans.

	Varieties			
	TP	***TNP***	***NP***	***NNP***
% FFA	0.48^{b}±0.35	0.70^{a}±0.02	0.42^{b}±0.01	0.58^{a}±0.13
Iodine value (g I_2/100g)	95.40^{a}±0.28	101.30^{b}±0.05	98.27^{a}±4.53	96.26^{a}±2.44
Peroxide value (meq/kg)	7.35^{b}±0.02	21.72^{a}±0.35.0	10.72^{c}±34.43	10.31^{c}±20.03
Saponification value (mgKOH/g)	147.30^{b}±0.80	168.85^{a}±0.30	144.93^{b}±5.7	164.17^{a}±3.87
TBA value (mgMDA/Kg)	0.023^{b}±1.5	0.034^{a}±1.9	0.037^{a}±0.0	0.040^{c}±0.5

Values are mean ±standard deviation. Means with same superscript letter across the same row are not significantly different (p>0.05). TP = Tox parboiled ; TNP = Tox non parboiled ; NP = Nerika parboiled; NNP = Nerika non parboiled; FFA = free fatty acids; TBA =Thiobarbituric acid.

Peroxide formation is an indication that lipid oxidation is on-going, these compounds react with low molecular weight metals to produce free radicals that are capable of further lipid oxidation [49]. The peroxide value of the crude rice bran oil was found to be around 10 meqO_2/kg (Table 1) which was not within the range of rancid oils (20 to 40 meqO_2/kg) as proposed by Akubugwo and Ugbogu [50].This could be as a result of low concentration of Cu and Fe in the crude rice oil, high level of tocopherol and oryzanol and low level of lipooxigenase; since there are strongest pro-oxidant [51].This value might explain the low peroxide value obtained for the oil. According to Codex Alimentarius Commission [52], the acceptable limit of peroxide value for rice bran oil is < 10meq/Kg [53]. The peroxide values fall within the acceptable limit. Again, it has a better oxidative stability and hence less chance of getting rancid than Indian rice bran oil as reported by Patil et al. [26] and Madhavi and Soroja [34].

3.1.4 Saponification value

Table 1 also presents the saponification values of the rice brand oils. It revealed a decrease in the saponification value of parboiled Tox and parboiled Nerika rice bran oils, indicating that they have weightier triacylglycerol than their non-parboiled variety. Saponification value indicates the average molecular weight of triglycerides in oil. Saponification value is inversely related to the average molecular weight of fatty acids in oil. According to Codex Alimentarius [54] and the APCC Standards [55], the saponification values (SV) of oils should range between 250-260 mg KOH/g oil and 248-268 mg KOH/g oil respectively. A range of 179-195 was proposed by Rossell [56] while Farooq et al. [51] obtained values ranging from 177-190 on four varieties of Pakistani bran oil. Ndop rice bran oil of the selected varieties had saponification values ranging between 144.93 and 168.85, indicating long chain fatty acids on triglycerides. Also, the low saponification values observed might be due to high level of impurities, as indicated by Kirschenbauer [57], who stated that high saponification values recorded for almond seed oil suggested low level of impurities. High saponification value indicates that oils are very useful in the production of liquid soap and shampoo. Therefore, the low saponification value obtained from Ndop rice bran oil shows that it has low potential for use in the production of liquid soap and shampoos. The variation in the physical and chemical characteristics of the parboiled and non-parboiled rice cultivars may be attributed to the source and milling process of rice polishing industry.

3.1.5 TBA value

The TBA value, which is an index of lipid oxidation and is a measure of malondialdehyde (MDA), a minor component of fatty acids formed upon degradation of the polyunsaturated acids content of oils. It measures hydroperoxides and aldehydic secondary oxidation products of the oils were quite low in rice bran oils [58]. Oil in good condition has TBA value of 0.02–0.08 MDA/kg [59]. A high oxidative stability of rice bran oil due to low TBA value, exhibited in the present analysis, compared with those of conventional vegetable oils [60], could be attributed to a significantly higher level of mono unsaturated fatty acids, which is less prone to oxidation than polyenoics (PUFA) [60]. Moreover, a high resistance to

oxidation of rice bran oil might be explained due to the presence of high content of γ-oryzanol and α-, γ- and δ-tocopherols; well-known natural antioxidants [51] indicating that it is a good oil for consumption.

The effect of parboiling on the quality of rice bran oil was also assessed in this study. The significant decrease in the acid value of the parboiled Tox and Nerika rice bran oils can be explained by the fact that the parboiling process reduces the hydrolytic activity of lipase enzymes present in the rice bran oil. Thus, parboiling increases the storage capacity of rice bran oil and serves as an adequate method of inhibiting lipase enzyme activity. Parboiling decreased iodine value of Tox rice bran oil, and slightly increased the iodine of value of Nerika rice bran oil. However, according to Tukey Honest Significant Differences (HSD), parboiling did not significantly influence the iodine value of rice bran oil in this study since $p>0.05$. Parboiling therefore doesn't have a great effect on the stability of Ndop rice bran oil. On the contrary, parboiling significantly ($p<0.05$) decreased the peroxide value of Tox rice bran oil. Lipase and lipoxygenase enzymes are mainly responsible for the formation of hydro-peroxides. The decrease in peroxide value can be explained by the fact that parboiling treatments might have suppressed the activity of these respective enzymes, leading to reduced levels of peroxide in the rice bran and consequently in the rice bran oil. Similar reduction in peroxide value of rice bran after parboiling has been reported by Patil *et al*., [26]. On the other hand, parboiling had an insignificant effect on peroxide value of Nerika rice bran oil. Parboiling therefore, has a positive effect on Tox rice bran oil rancidity, and no significant effect on the rancidity of Nerika rice bran oil. The decrease in the saponification value of parboiled Tox and Nerika rice bran oil indicates that they have weightier triacylglycerides than their non-parboiled variety. Parboiling decreased the TBA values of Ndop rice bran oil. The higher TBA value observed in the non-parboiled rice bran oil could be due to lipase still being very active and hydrolysed the lipids in the rice bran freeing fatty acids and thus being ready for oxidation. This result is supported by Sharif [61] who reported highest TBA value in unstabilized rice bran followed by parboiled rice bran.

3.2 Fatty acids composition

The fatty acid composition of the oils extracted from the two varieties of rice bran oil is shown in Table 2. From this table it can be seen that the fatty acid compositions do not differ significantly between the varieties and according to the treatment (parboiled and non-parboiled). It also shown that rice bran oil is an unsaturated oil, with unsaturated fatty constituents ranging between 73.44 and 74.33% and the saturated counterparts between 25.66 and 27.17%.

The quality of fat is generally specified by the relative content of saturated fatty acids (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA) including the proportion or amount of essential fatty acids, i.e., linoleic acid (LA) and α-linolenic acid (ALA), as well as the proportion or amount of long chain polyunsaturated [62-64]. Rice Bran Oil is rich in monounsaturated fatty acids 42.62-43.44%, and also polyunsaturated fatty acids between 30.7 and 30.88%. These results are in accordance with those of Rangaswamy and Nasirullah [65] and Oluremi et al. [66]. PUFAs have been claimed to have a broad range of beneficial effects including lowering cholesterol, decreasing the risk of arrhythmia, lowering the blood pressure, preventing diabetes in pregnancy, and beneficial effects on joints (relief of arthritis). Both omega-3 and omega-6 PUFA are precursors of hormone-like compounds, which are involved in many important biological and biochemical processes in the human body. They are indispensable for the synthesis of prostaglandins, thromboxanes, prostacyclines and leukotrienes, and take part in the transport and oxidation of cholesterol. PUFAs, both of the n-6 and n-3 series are important constituents of the phospholipids of all cell membranes. Omega-6 polyunsaturated fatty acids (PUFA) are precursors of a number of key mediators of inflammation. An intermediate arachidonic acid may undergo cyclooxygenase pathway leading to the formation of prostaglandin and thromboxanes or Lipoxygenase pathway to form leukotriene [67].

The saturated, mono-unsaturated and polyunsaturated fatty acids that were more predominant in the oil were palmitic, oleic and linoleic acids respectively. Prospective epidemiological studies in very large populations confirmed that dietary linoleic acid is predictive of reduced CVD [17,51,65,68]. Thus, one paradigm became established, that linoleic acid, an omega-6 PUFA, is cardio protective. In human nutrition, the MUFAs play an important role due to their hypocholesterolemic action, reducing the risk of arteriosclerosis. Dietary fat affects blood serum cholesterol in humans, and consequently, can influence the occurrence of coronary heart disease compared to SFAs; and also the rich content in MUFAs indicates that rice bran oil can be good for cooking processes and seasoning like olive oil if fractionated into oleic fractions. These results are in agreement with those of Farooq et al. [51] and similar to those of Muhammad et al. [17].

Table 2: Fatty acids composition of oil extracted from Tox parboiled, Tox non-parboiled, Nerika parboiled and Nerika non-parboiled rice bran.

Fatty acids	Common Names	TP	TNP	NP	NNP
C14:0	Myristic acid	0.81±0.03	0.68±0.05	1.06 ± 0.05	0.56±0.02
C16:0	Palmitic acid	21.15±0.58	20.98±0.05	21.71 ± 0.18	21.98±0.04
C18:0	Stearic acid	2.74±0.10c	2.49±0.01	3.06 ± 0.06	2.79±0.10c
C18:1	Oleic acid	42.62±0.05	43.44±0.05c	43.05 ± 0.22	43.25±0.05
C18:2 (ω−6)	Linoleic acid	29.60±0.01	29.57±0.01c	28.58 ± 0.09	29.03±0.12
C18:3(ω−3)	Linolelenic acid	1.22±0.23	1.31±0.01	1.50 ± 0.10	1.41±0.05
C20:0	Arachidic acid	1.70±0.01	1.52±0.02	1.35 ± 0.04	1.33±0.02
SFA	Saturated fatty acid	26.40± 0.04	25.66±0.05	27.17 ± 0.06	26.64±0.01
UFA	Unsaturated fatty acid	73.44 ± 0.21	74.33±0.01c	73.12 ± 0.18	73.69±0.02
MUFA	Mono unsaturated fatty acid	42.62 ± 0.51	43.44±0.05	43.05 ± 0.07	43.25±0.01
PUFA	Polyunsaturated fatty acid	30.82±0.02c	30.88±0.05	30.07 ± 0.07	30.44 ± 0.21
PUFA/SFA		1.17	1.20	1.11	1.14
AI		0.30	0.29	0.31	0.31
ω−3/ω−6		0.04	0.04	0.05	0.05

ω−3= omega 3; ω−6= omega 6; SFA= Saturated fatty acid; MUFA= Monounsaturated fatty acid; PUFA= Polyunsaturated fatty acid; UFA= unsaturated fatty acid; AI= artherogenic Index. TP = Tox parboiled ; TNP = Tox non parboiled ; NP = Nerika parboiled; NNP = Nerika non parboiled

For the n-3 PUFA family, the highest proportions were found in TNP and NNP (30.88% and 4.37% respectively, and the lowest proportion was observed in NP. PUFA/SFA is an indicator used to evaluate lipid quality. Its recommended minimum value is 0.45 by the British Department of Health [69]. The levels obtained here were greater than 0.45 indicating good quality oil. Several studies have shown that an acceptable balance between n-6 and n-3 PUFAs is associated with an improvement in whole body glucose tolerance, obesity, inflammatory, and other metabolic dysfunctions [70,71]. WHO recommends that the n-6 PUFA/n-3 PUFA ratio should not exceed 10 [72], while the European Nutritional Societies suggest that this ratio should not exceed 5, for the prevention of inflammatory, cardiovascular, and neurological disorders [71]. All the examined oils exhibited a n-6/n-3 ratio below 5.

The artherogenic index (AI) is proposed to evaluate risky factors that are implicated in coronary heart disease development by Sanina et al. [73]. It was <0.4 in the investigated rice bran oils, owing to the high n-6 PUFA contents and low n-3 ratios. The results suggest that the oils might be beneficial to cardiovascular health.

The PUFA /SFA ratio of foods have been widely used to indicate their potential to lower cholesterol levels. A PUFA /SFA ratio of 0.2 is associated with hypercholesterolemia and a high risk of cardiovascular disorders while a ratio greater than 0.8 (as in the case of rice bran oils) is desirable for maintaining cholesterol to a good level, and to reduce coronary heart disease [74-76]. This ratio of 1.19 tends to suggest that rice bran oil has the potential to be used in the dietary management of certain coronary heart disease.

3.3 Effect of oven drying on the chemical quality of the oil

The effect of oven drying on oil quality indices for Tox variety of Ndop rice bran oil is shown on Figure 1. Figure 1(a) shows the effect of oven drying on the acid value of Tox Ndop rice bran oil. Tox non-parboiled rice bran oil has its lowest and highest acid values at 30 and 12 hours of oven drying respectively, while Tox parboiled rice bran oil has its lowest and highest acid values at 12 and 30 hours of oven drying respectively. In general acid value increased up to 12 hours and then decreased with no much change for the non-parboiled but with a slight increase. The effect of oven drying on oil quality indices for Nerika variety of Ndop rice bran oil is shown on Figure 2. For acid value, Nerika non-parboiled rice bran oil has its lowest and highest values at 0 and 24 hours of oven drying respectively, while Nerika parboiled rice bran oil has its lowest and highest values at 24 and 30 hours of oven drying respectively. Acid value generally increases with that of the non-parboiled being higher than that of the parboiled at all drying times.

The effect of oven drying on the iodine value of the Tox variety of Ndop rice bran oil is shown in Figure 1(b). Tox non-parboiled rice bran oil has its lowest and highest iodine values at 0 and 12 hours of oven drying respectively, while Tox parboiled rice bran oil has its lowest and highest iodine values at 0 and 30 hours of oven drying respectively. Iodine value increased up to 12 hours and then decreased with no much change for the non-parboiled but with a slight increase. For Iodine value, Nerika non-parboiled rice bran oil has its lowest and highest values at 12 and 30 hours of oven-drying respectively, while Nerika parboiled rice bran oil has its lowest and highest values at 30 and 6 hours of oven-drying respectively. Iodine value of non-parboiled generally increases while that of parboiled decreases slightly and progressively. The values for non-parboiled was higher than that of parboiled. Iodine value expresses the unsaturation level of oil [77]. It indicates the oil's stability and health properties [34]. Decrease of iodine value during oven-drying is indication of vulnerability to oxidation and production of free radicals when enzyme are still activated particularly for non-parboiled samples or by autoxidation, while the increase is therefore a stability after oven drying due to destruction of lipases during parboiling [34] as reported by Yuliana et al. [25].

The effect of oven drying on the peroxide value of Tox variety of Ndop rice bran oil is shown in Figure 1(c). Tox non-parboiled rice bran oil has its lowest and highest peroxide values at 18 and 0 hours of oven drying respectively, while Tox parboiled rice bran oil has its lowest and highest peroxide values at 6 and 18 hours of oven drying respectively. Peroxide value generally decreased with oven drying for both TP and TNP. For Peroxide value, Nerika non-parboiled rice bran oil has its lowest and highest values at 18 and 0 hours of oven drying respectively, while Nerika parboiled rice bran oil has its lowest and highest values at 0 and 24 hours of oven drying respectively. Peroxide value for parboiled was higher than that of parboiled and the change of both with respect to drying time is almost constant. The Increase of peroxide value is an indication of oxidation during oven drying while a decrease could be due to low oxidation or to transformation of primary products into secondary products of oxidation [78]. The acceptable limit of peroxide value for rice bran oil is < 10meq/Kg [53].

The variability in saponification value of Tox variety of Ndop rice bran oil with oven-drying is shown in Figure 1(d). Tox non-parboiled rice bran oil has its lowest and highest saponification values at 30 and 18 hours of oven drying respectively, while Tox parboiled rice bran oil has its lowest and highest saponification values at 0 and 30 hours of oven drying respectively. In general saponification value fluctuated for both; however it was consistently higher for TP irrespective of drying time. For Saponification value, Nerika non-parboiled rice bran oil has its lowest and highest values at 0 and 18 hours of oven drying respectively, while Nerika parboiled rice bran oil has its lowest and highest values at 24 and 0 hours of oven drying respectively. Saponification value increases and then decreases at 24 and 30 hours for non-parboiled. For parboiled, it generally decreases and increases at 30. The values for non-parboiled are higher than those of parboiled indicating fatty acids with low molecular weight or short chain.

The effect of oven-drying on the thiobarbituric acid value of Tox variety of Ndop rice bran oil is shown in Figure 1(e). Tox non-parboiled rice bran oil has its lowest and highest thiobarbituric acid values at 24 and 12 hours of oven drying respectively, while Tox parboiled rice bran oil has its lowest and highest thiobarbituric acid values at 0 and 6 hours of oven drying respectively. In general TBA value increased briefly for both at 6 hours. TBA further increased at 12 hours for TNP and then all decreased with drying time. For Thiobarbituric acid, Nerika non-parboiled rice bran oil has its lowest and highest values at 30 and 0 hours of oven drying respectively, while Nerika parboiled rice bran oil has its lowest and highest values at 18 and 30 hours of oven drying respectively. TBA gave a sort of sigmoid curve. It decreased from 0 to 6 hours, remained constant till 18 hours and then decreased till 24 hours and remained constant thereafter. NP did not change much. Globally, the oil quality indices increased with drying time for parboiled Nerika except for peroxide value. The increase in TBA is indication of rancidity due to lipooxygenase activities or autoxidation; while a decrease can be an indication of the volatility of such secondary product or can also be explained by low secondary products forms like aldehydes and ketones.

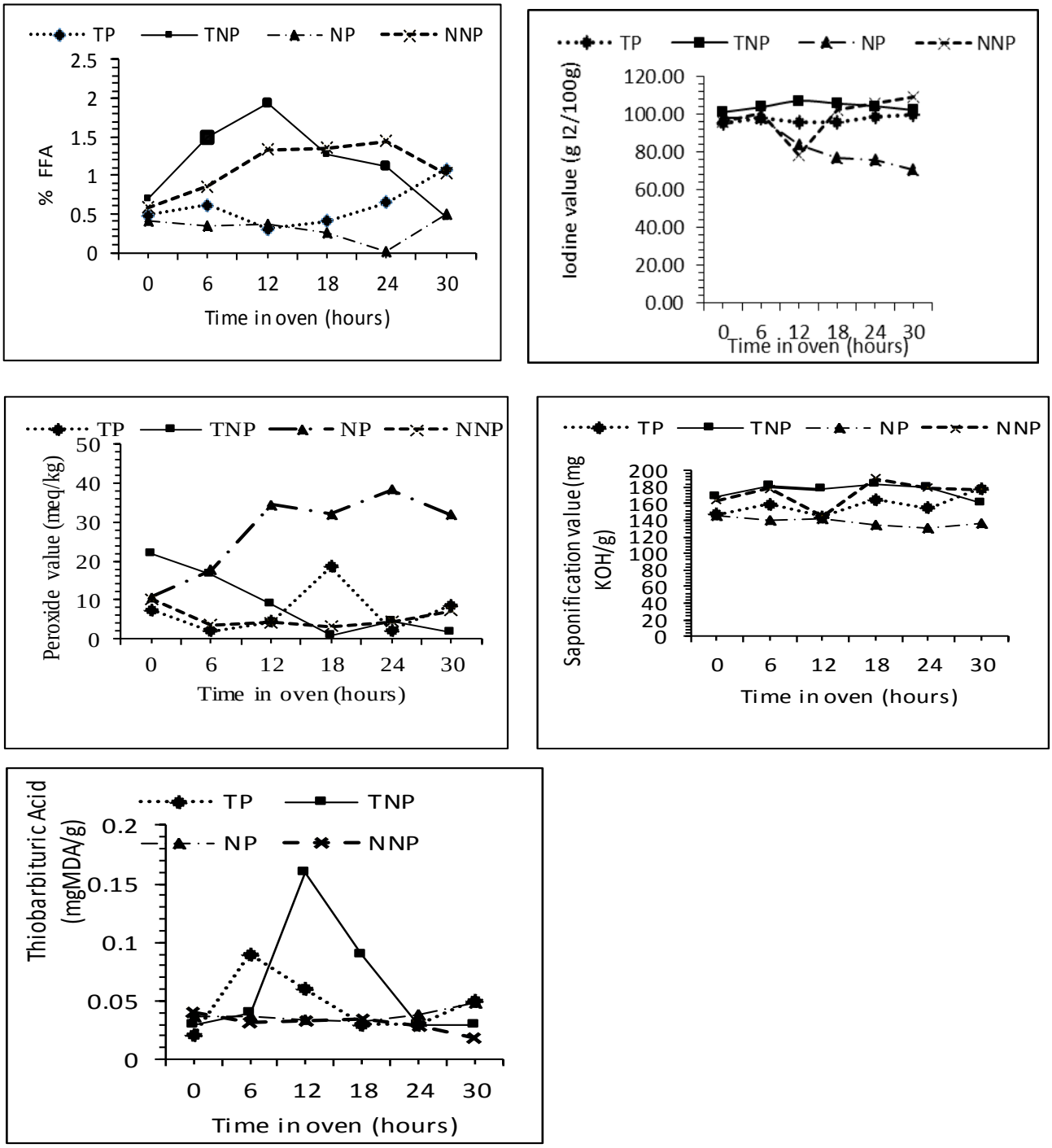

Fig. 3 The effect of oven drying on (a) Acid value (b) Iodine value (c) Peroxide value (d) Saponification value (f) Thiobarbituric acid value of Tox and Nerika parboiled and non parboiled.

3.4 Effect of oven drying on the yield of rice bran oil

Effect of oven drying on the yield of rice bran oil is shown in table 3. Oven drying altered the oil yields of the various rice brans in different ways. Tox parboiled rice bran had highest oil yield when oven dried for 24 hours and lowest when dried for 30 hours. Tox non-parboiled had highest oil yield without oven drying was done, and lowest oil yield when oven dried for 6 hours. Nerika parboiled rice bran produced highest oil without oven dying and Nerika non-parboiled produced its highest oil yield when oven dried for up to 30 hours. The percentage of oil yielded by the Tox rice bran variety was higher than that of Nerika rice bran variety. Tox is therefore a better variety in terms of quantity for oil extraction and will thus be better for commercial purposes. Parboiling improves on Ndop rice bran oil yield. The higher percentage oil yield of both parboiled Tox and Nerika varieties tie with the reports of Khoei *et al*., (2016) and Amarasinghe *et al*., (2009) which state that parboiled rice bran gives a higher oil percentage than raw rice bran. This may be due to the fact that parboiling releases the oil in the grain and results in outward migration of the oil into the bran.

Table 3: Percentage (v/w) oil yield for Tox parboiled, Tox non-parboiled, Nerika parboiled and Nerika non-parboiled rice bran as a function of oven drying time.

Time in oven (hours)	***% v/w oil yield***			
	TP	***TNP***	***NP***	***NNP***
0	13.75	12.75	6	5
6	10.32	4.78	2.42	2.01
12	11.43	8.46	2.11	1.87
18	11.25	8.15	2.13	3.35
24	18.51	10.33	3.28	2.06
30	2.41	12.70	1.08	5.57

TP = Tox parboiled; TNP = Tox non parboiled ; NP = Nerika parboiled ; NNP = Nerika non parboiled

4. Conclusions

The best Ndop rice bran for a good quantity of oil extraction is Tox parboiled rice bran. Ndop rice bran is a good source of edible oil whose quality can be improved by parboiling and oven drying, as at 80% it's oil quality parameters fall within the acceptable limit for good edible oil according to the standards of Codex Alimentarius. Artherogenic index (AI) and PUFA/SFA ratio were in good ranged to conclude on the use of rice bran oil to protect against risk factors that are implicated in coronary heart disease

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