# A comprehensive review of the potentials of rice bran oil processing in Nigeria

**U. Garba[1,4,*] R. Singanusong[1,2] B.B. Ismail[3,4]**

[1*] Department of Agro-Industry, Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Thailand

[2] Centre of Excellent in Fat and Oil Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Thailand

[3] College of Biosystems Engineering and Food Science, Zhejiang University, Hangzhou, China

[4] Department of Food Science and Technology, Faculty of Agriculture, Bayero University, Kano, Nigeria

*(*) CORRESPONDING AUTHOR: E-mail: ugarba.fst@buk.edu.ng*

Population increase and rising awareness on the importance of a healthy diet leads to high demands of high quality vegetable oil. As such, other sources of vegetable oil need to be explored to meet the current demand, especially in a country like Nigeria with the largest population in the African continent. Rice bran oil (RBO) from rice bran is a popular edible oil due to its numerous nutritional and health promoting qualities. Additionally, its rich nutrient and phytochemicals profile, high anti oxidant potential and promising health benefits have been the focus of current research. Nigeria has an exciting potential for establishing RBO extraction plants by both local and foreign investors due to the current booming in rice production. Currently, data regarding the availability of any commercial RBO processing plant in Nigeria is obscure. This paper will provide an overview of the potentials of RBO processing in Nigeria.

**Keywords:** Vegetable oil, rice bran oil, phytochemical compounds, Nigeria, rice bran oil business.

## 1. INTRODUCTION

Vegetable oils form an important portion of the human diet and a chief source of edible lipids accounting for more than 75% of the total lipids consumed globally. They provide a substantial amount of essential fatty acids, liposoluble vitamins and act as an important medium in cooking. Further, from the perspective of nutrition, vegetable oils are particularly rich in antioxidants including vitamin E and phenols and although they do not supply the body with energy but perform other vital function including maintenance of normal body temperature and the protection of body tissues [1, 2].

Globally, the production of vegetable oils has witnessed steady growth with an annual increase of about 5% since 2007. About 185.78 million metric tons of vegetable oils from plants such as palm, palm kernel, coconut, cottonseed, olive, peanut, rapeseed, soybean and sunflower seed were produced between 2016-2017. Palm oil is the vegetable oil with the highest quantity of production and consumption of about 65.5 million metric tons since 2013. The largest producers of palm oil include Indonesia, Malaysia followed by Thailand, Nigeria, and Columbia [3]. Nigeria with the population of about 190 million as of 2017 is the most populous country in Africa and seventh in the world. It has the world's 20th largest economy, valued at more than $500 billion and $1 trillion in terms of nominal GDP and purchasing power parity respectively [4]. Apart from petroleum, which is the major source of foreign exchange, Nigeria is endowed with a vast portion of land with a favourable climate and good soil suitable for agricultural activities. Many different oil-bearing seeds are produced in Nigeria including cottonseed, groundnut seed, palm kernel seed, sesame seed, the melon seed of which vegetable oil can be extracted from. According to the statistics provided by [4], Nigeria consumes 3.024 million tons of vegetable oil with an average of 11.38 kg per person in 2013. The major vegetable oils used in Nigeria include palm oil, groundnut oil, cottonseed oil, palm kernel oil, coconut oil and sesame seed oil.

With the population growth and rising awareness on the significance of a healthy diet edible vegetable oils are expected to be popular among consumers for their rule in the prevention of diseases and health improvements. Also, as the demands increasingly surpass the production of vegetable oils, there is the need to look for non conventional sources of vegetable oils in order to satisfy the need of the rising population [2].

Rice (Oryza sativa) is among the most vital cereal crops cultivated around the globe and ranks second to wheat in terms of the global production output. It is mostly consumed in its polished form as staple food for more than half of the world's population [5-8]. The outer layer of brown rice obtained as a by-product of milling industry is known as rice bran [5]. Rice bran is one of the most abundant and equally important by-products of the rice milling industry with the global production potential of 29.3 million tons per annum [8]. Several vital nutrients including vitamins, minerals, and some phytochemicals, such as gamma-oryzanol, tocopherols, tocotrienols and phytosterols were reported in rice bran [2, 9]. It contains essential micronutrients and non-essential phytochemicals and is used as animal feed or sometimes considered as agricultural food waste. The rice bran oil (RBO) which comprised 15 to 25% of the bran has been considered among the most valuable and healthy oils due to its good nutritional composition which includes vitamin E (α-tocopherol and tocotrienol), vitamin K and γ-oryzanol [10]. The γ-oryzanol is peculiar and important components of RBO because of its health benefits such as lowering serum cholesterol, anti-oxidation, anti-carcinogenic, and anti-inflammation [11]. In rice bran, γ-oryzanol comprises 9.8 g/kg oryzanol which is 13-20 times more than a total of tocotrienols and tocopherol in terms of concentration [8]. The bran is also known to contain higher phenolic content than wheat bran [12]. The abundance of phytochemicals and functional compounds in both the rice bran and RBO has drawn the attention of chemists and pharmacologist in recent years [5].

The RBO was found to be used for foods, cosmetics, and pharmaceutical applications. Solvent extraction using hexane is the major and most widely used method for the commercial extraction of RBO [13]. Several studies conducted on the RBO found no adverse effect on humans due to it's consumption [10]. The aim of this review was to investigate the current potential and uses of the rice bran, and the potential for setting up RBO extraction plants in Nigeria as well as the challenges and including some of the prospects and constrains.

## 2. REVIEW OF RICE PRODUCTION AND CONSUMPTION IN NIGERIA

Nigeria is one of the world's largest producers of rice. In 2017 alone, about 3.780 million tons of milled rice were produced making it 16th world's largest producer of rice [14]. The production of rice in Nigeria started around 1500 BC with an indigenous red grain species Oryza gaberima grown in the Niger Delta region with low a yield. Later in the 1980s, Oryza Sativa with higher yield was introduced and is now grown in almost all Agro-economic zones of the country [15]. The Oryza sativa was believed to originate from South-East Asia, and the O. glaberrima from Africa [16]. Some of the earlier released and popular rice varieties grown in Nigeria include Faro 44, Faro 52, Faro 57, Faro 60 (NARICA L-19), Faro 61 (NARICA L-34), Jamila, Jeep, Yardas and Kwandala (17). The major areas of rice production in Nigeria are Kebbi, Kano, Ebonyi, Anambra, Niger, and Taraba. Kebbi is the major rice producing state in Nigeria. The data for the production and consumption of rice in Nigeria from 2000 to 2018 is presented in Table I.

Nigeria with the population of 193 million, according to the National Population Commission, is the most populous country in Africa, and currently the largest producer and consumer of rice in the West African region. At present, about 80% of the Nigerian population consumes rice as the staple diet and the consumption is increasing rapidly with an increasing population. The country has an annual demand of about 5.2 million tons of milled rice. Besides the 1.9 million tons annual rice importation, it still needs to produce another 3.3 million tons to meet its annual demand [18]. In 2017/2018, Nigeria's milled rice consumption was estimated at 4.8 million tons, from around 5.2 million tons in 2016/2017 (a drop of about 5%). This may be due to the country's hike in price coupled with low purchasing power during this period, which forced consumers to shift to less expensive local staples such as bread, garri (fermented product from cassava), and other wheat products [19]. The Nigerian milled rice production has reached up to 3.780 million tons in 2018 [14]. Nigeria has the viable potential of being a self-sufficient country in terms of rice production for food and industrial raw material as well as the export purposes, due to its good agricultural land. However, several factors such as lack of research and its applications, pest and disease management, mechanization, irrigation facilities, government interventions have always been the limiting factors to attaining the self-sufficiency [6].

### 2.1. STATUS OF RICE MILLING INDUSTRIES IN NIGERIA

Rice paddy is obtained after harvesting and threshing with about 20% moisture content, which is dried down to 14% moisture content before storage.

**Table I** - Rice production in Nigeria (2000-2018)

| Production of Rice in Nigeria | | | | |
|---|---|---|---|---|
| Year | Rice paddy (MT) | Milled rice (MT) | Growth rate (%) | Yield (MT/HA) |
| 2000 | 3,298,000 | 1,979,000 | 66.00% | 1 |
| 2001 | 2,752,000 | 1,651,000 | -1657% | 1 |
| 2002 | 2,929,000 | 1,757,000 | 6.42 | 1 |
| 2003 | 3,116,000 | 1,870,000 | 6.43 | 1 |
| 2004 | 3,303,000 | 2,000,000 | 6.95% | 1 |
| 2005 | 3,567,000 | 2,140,000 | 7.00% | 1 |
| 2006 | 4,042,000 | 2,546,000 | 18.97% | 1 |
| 2007 | 3,186,000 | 2,008,000 | -21.13% | 1 |
| 2008 | 4,179,000 | 2,632,000 | 31.08% | 2 |
| 2009 | 3,546,250 | 2,234,000 | -15.12% | 2 |
| 2009 | 3,546,250 | 2,234,000 | -15.12% | 2 |
| 2010 | 4,472,520 | 2,818,000 | 26.14% | 2 |
| 2011 | 4,612,614 | 2,906,000 | 3.12% | 2 |
| 2012 | 5,432,930 | 3,423,000 | 17.79% | 2 |
| 2013 | 4,823,330 | 3,038,000 | -11.25 | 2 |
| 2014 | 6,002,831 | 3,782,000 | 24.49 | 2 |
| 2015 | 6,256,228 | 3,941,000 | 4.20 | 2 |
| 2016 | 6,070,813 | 3,780,000 | -4.09 | 2 |
| 2017 | NA | 3,780,000 | 0.00 | 2 |
| 2018 | NA | 3,780,000 | 0.00 | |

Note: MT=metric tons, HA= hectare, NA=Data not yet available
Source: Data for paddy production was obtained from FAO/Fact fish, [77] and data for milled rice production from Index Mundi, [14].

During the series of milling processes, the outermost husk layer is removed to obtain the brown rice which is further polished to remove the bran and germ layer to get the white rice kernels [20]. Milling can be done using a single-pass, single-stage local mill or multistage process involving several operations and machines to process the paddy to brown or white rice [20].
As the price for imported rice in Nigeria increased, the quality of locally produced rice improved and consumers are now accepting and appreciating the locally produced rice. Nigeria has put some restriction to discourage the import of rice to the country through land borders and has taken a step to increase access to financing in order to encourage local agricultural production. This effort is currently helping to boost the local rice production and milling sector and reduce the country's over-dependence on imports [21]. As a result, there is a growing number of large-scale commercial rice milling industries in the country with a reasonably high capacity (Tab. II). However, some of the rice mills are not operating at their fullest capacity due to some challenges like electricity supply, insufficient paddy supply and lack of funds to inject into capacity-intensive milling.
In a review on challenges facing rice processing in Nigeria by [6], it was reported that a significant improvement in rice processing in the country has been made over the years since the 1990s moving from traditional paddy sun dying and milling process to a more mechanised process. Presently, Nigeria's paddy sells at a local market price of N250,000 ($500) per ton and N260,000 ($520) per ton for milled rice. However, the mills indicated that the price difference is too low to cover the milling and marketing cost. According to some local farmers, many of the investors in the integrated rice processing or farming are also among the rice importers in the region [19]. Perhaps, this can serve as the barrier to the development of the integrated rice mills in the country.



## 2.2. RICE BRAN AND ITS USES IN NIGERIA

Agricultural by-products like rice bran are often considered as waste and thus, great potentials in terms of the nutraceutical benefit and oil content as wasted and underutilised [7]. The rice bran (Fig. 1) account for 5-8% of rough rice and 2-3% polishing. In many developing countries including Nigeria, it is frequently used as animal feed [8, 22].
Rice bran has also been used for the extraction of protein concentrate and isolates [24]. In line with the current production of 2017, Nigeria has an estimated potential of about 304,000 to 490,000 metric tons of rice bran. Survey has shown that most of the rice bran produced by the Nigerian rice millers are mostly used as furnace fuel for drying or sold as fish and cattle feeds, while it is a waste in the majority of cases [25, 26]. The bran has also been used in formulating diets for fish, poultry and pig production [27]. Rice bran has unique and powerful endogenous lipoxygen-

**Table II -** List of some commercial rice milling industries in Nigeria

| S/N | Rice mills | Annual production capacity (Tonnes) | Location (State) | References |
|---|---|---|---|---|
| 1 | Stalion Group | 150, 000 | Kano | [73] |
| 2 | Stalion Group | 80,000 | Benue | [73] |
| 3 | Stallion Group | 230,000 | Lagos and Ogun | [73] |
| 4 | Olam farm | 105,000 | Nasarawa | [76] |
| 5 | Umza International Farm limited | 72,000 | Kano | [76] |
| 6 | Amarava Rice mill | 207, 360 | Kano | [75] |
| 7 | Milan Group | 100,000 (estimated) | Lagos and Ogun | [73] |
| 8 | Anambra rice | 141,000 | Anambra | [73] |
| 9 | Wacot rice mill | 120,000 | Kebbi | [76] |
| 10 | Labana rice (2 mills) | 8,000 | Kebbi | [76] |
| 11 | Mikap rice mill Nigeria Ltd | 15-20,000 | Benue | [73] |
| 12 | Mas rice mill | Unknown | Gombe | [76] |
| 13 | Fada rice | Unknown | Ogun state | [76] |
| 14 | Igbemo rice | Unknown | Ekiti | [76] |
| 15 | Mama Happy rice | Unknown | Niger | [76] |
| 16 | IRS mills Kano | Unknown | Kano | [73] |
| 17 | Ashi mill | Unknown | Benue | [73]] |
| 18 | Ebonyi state rice mill | Unknown | Ebonyi | [73] |
| 19 | Imcota Integrated mill | Unknown | Lagos | [73] |
| 20 | Quarra mill | 30,000 <50% utilization | Kwara state | [74] |
| 21 | Attajiri rice mill | Unknown | Sokoto | [73] |
| 22 | Integrated grains rice mill | Unknown | Enugu | [73] |
| 23 | Adani mill | Unknown | Enugu | [73] |
| 24 | Atalu mill | Unknown | Jigawa | [73] |
| 25 | Dominion rice mill & farm | Unknown | Taraba | [73] |
| 26 | Al-uma mill | Unknown | Taraba | [73] |
| 27 | Omar mills | Unknown | Taraba | [73] |
| 28 | Kare hited mills | Unknown | Zamfara | [73] |
| 29 | Atashi rice mill | Unknown | Jigawa | [73] |
| 30 | Golden penny Rice mill | Unknown | Lagos | [73] |
| 31 | Sokoto premier rice mill | Unknown | Sokoto | [73] |
| 32 | Badaggi Mill | Unknown | Niger | [73] |



ase enzymes which are activated during milling [28]. When the bran layer is removed from the endosperm after milling, the contact of the enzymes and oil in the bran leads to hydrolysis that leads to a breakdown of the oil and the release of free fatty acids and glycerol that, in turn, causes a reduction in its quality and shelf life. This degradation can be very high to the extent that the usefulness of the bran for human and animal consumption is lost and the bran oil produced can only be used as boiler's fuel [22]. Rice bran can degrade in approximately 6 hours after normal milling conditions rendering it unpalatable and unsuitable for use as a human food [29]. The rate of hydrolysis varies with temperature, humidity, and other factors. Such rapid hydrolysis and degradation of the bran can be minimised through a stabilisation process that can be achieved using various methods such as steaming [30, 31], microwave treatment [32], subcritical water treatment [33], ohmic heating [31, 34] etc. Rice bran contains about 18-23% oil, which is rich in essential fatty acids [27]. The fatty acids in rice bran include 16:0 palmitic acid (2.73 g/100g), 18:0 stearic acid (0.37 g/100g), 18:1 oleic acid (6.86 g/100g), 18:2 linoleic (6.35 g/100g) and 18:3 α-linolenic acid (0.26 g/100g) [28]. It is also rich in dietary fibre, vitamin B and E, and minerals such as iron, calcium, potassium, chlorine, magnesium, and manganese [27]. A full-fat rice bran contains 8.41% moisture [28], 16.56% protein (N*6.25), 21.3% fat, 8.3% Ash, 49.4% total carbohydrates and 11.4% crude fiber [35]. A defatted rice bran has 8.37% moisture, 14.27% protein, 1.8% crude fibre, 14.59% ash, 58.41% carbohydrate and 12.44% reducing sugar [8]. The defatted rice bran after the oil is normally sold as an animal feed [28].

## 3. RICE BRAN OIL (RBO)

RBO is considered as one of the largest underutilised agricultural commodities in the world [36]. RBO,

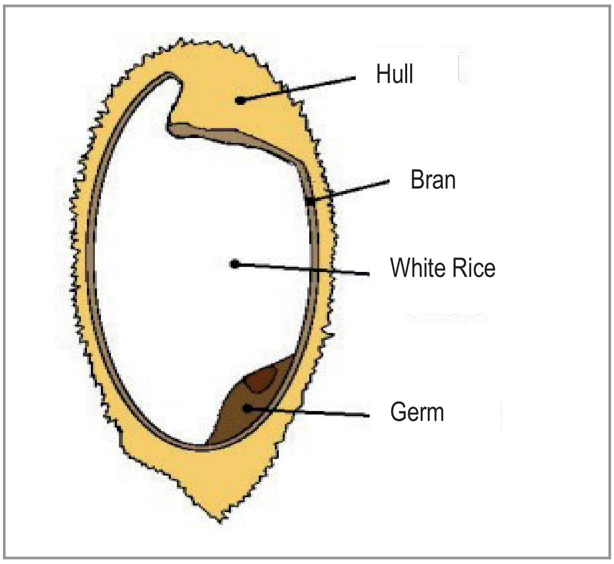


**Figure 1 -** Structure of rice grain
Source: [24]

which constitute 20-25 wt% of rice bran, is considered as a uniquely rich source of bioactive phytochemicals with particular potentials in nutrition, pharmaceuticals and cosmetics. RBO, also referred to as rice oil, it is not popular globally but its demand is growing because of its health benefits [8]. It has recently been introduced into the consumer market as a comparatively new oil [10]. RBO is a unique edible oil extracted from the bran which is removed from the outer layer of brown rice during the milling process particularly the polishing stage [7]. It is a popular oil in many Asian countries such as Japan, India, China, Thailand, and Bangladesh [37, 38]. It has been largely considered as 'Premium Edible Oil' in countries like Japan, Taiwan, China, Thailand, and Korea [8]. India and Thailand were the most successful countries in RBO production [29].

## 3.1. CHEMICAL COMPOSITION, NUTRITIONAL AND HEALTH PROPERTIES OF RBO

### 3.1.1. Fatty acids profile of RBO

In humans and other organisms, fatty acids play vital roles and in addition to proteins and carbohydrates, they constitute the main components of biological matter. Fatty acids in RBO are structurally categorised into different classes with different functions including saturated fatty acid (SFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) [2]. The fatty acids composition of RBO is presented in Table IV. SFA in RBO include myristic, palmitic and stearic acids. Regular intake of saturated fatty acids has been linked to the increase in cholesterol level which is associated to the increase in mortality due to coronary heart disease (CHD) [39]. On the other hand, oleic acid is a MUFA and it has been reported to play a role in the prevention of cardiovascular diseases through several mechanisms. Moreover, the lower incidences of cardiovascular diseases in the Mediterranean region compared to other parts of the world are associated with the high consumption of MUFA [2]. Dietary consumption of MUFAs results in reductions of glucose and blood pressure levels and to an increase in high-density lipoprotein (HDL) in diabetic patients [40]. The PUFA present in RBO includes linoleic and linolenic fatty acids. These compounds with two or more double bonds are considered as essential fatty acids that cannot be synthesised in humans, yet they are necessary for health [41]. These fatty acids were reported to exhibit antiatherogenic and antithrombotic properties and affect the concentration of lipoprotein, membrane fluidity, functions of membrane enzymes and in the function and modulation of other compounds [2].

RBO has a good balanced fatty acid profile in line with the recommendation of World Health Organisation (WHO), American Heart Association's (AHA), and National Institute of Nutrition (NIN) [37]. The oil has been used in foods, pharmaceuticals, and cosmetics industries due to its unique properties and medicinal values [30]. RBO has been used for high-temperature cooking such as stir and deep frying due to its high smoke point of 23°C (450°F) and mild flavour. Food cooked with the RBO absorbs 15 to 20% less oil [37, 38]. RBO has been reported to exhibit antiatherogenic, hypolipidemic, and antidiabetic properties [42].

### 3.1.2. Phytochemicals composition

In addition to the presence of essential fatty acids and other types of fatty acids, RBO contains a good number of phytochemical compounds (Tab. IV), giving it the status of 'Heart oil' because of its cardiac friendly profile [43]. A crude RBO composed of triglycerides (81.3-84.3%), diglycerides (2-3%), monoglycerides (5-6%), free fatty acids (2-3%), waxes (0.3%), glycolipids (0.8%), phospholipids (1.6%), and unsaponifiable matter (4%) [37]. The unsaponifiable constituents of RBO include contains mainly tocopherols and tocotrienols (tocols or vitamin E) and Y- oryzanol, and other compounds at lower concentration including lecithin and carotenoids [44]. RBO is being regarded as a rich source of bioactive phytochemicals with antioxidant and chemopreventive properties [42].

## 3.2. GLOBAL PRODUCTION OF RICE BRAN OIL

The global production of RBO was estimated at over 1.2 million tons in 2015 and reached up to around 1.5 million tons in 2016 [45]. It was estimated to reach up to 1.76 Million tons in 2017 (Fig. 2). India is the largest producer of RBO globally. In 2014, Indian RBO market size was valued at over USD 600 million with

**Table IV-** Major classes of lipids in RBO and their fatty acid composition

| | | Fatty acids composition (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lipid class** | **wt%** | **Myristic** | **Palmitic** | **Stearic** | **Oleic** | **Linoleic** | **Linolenic** | **Arachidic** | **Saturated** | **Unsaturated** |
| Total lipids | 20.1 | 0.4 | 22.2 | 2.2 | 38.9 | 34.6 | 1.1 | 0.6 | 25.4 | 74.6 |
| Neutral lipids | 89.2 | 0.4 | 23.4 | 1.9 | 37.2 | 35.3 | 1.1 | 0.7 | 26.4 | 73.6 |
| Glycolipids | 6.8 | 0.1 | 27.3 | 0.2 | 36.5 | 35.8 | 0.2 | - | 27.6 | 72.4 |
| Phospholipids | 4.0 | 0.1 | 22.1 | 0.2 | 38.1 | 39.3 | 0.2 | - | 22.4 | 77.6 |

Source: [36]

a production potential of 1.4 million tons, although currently, it produces only about 0.9 million tons. China is the second with around 0.2 million tons, while Japan and Thailand with an estimated production of over 80,000 and 50,000 tons respectively [30, 45]. The global market for RBO has grown by around 3% during 2010-2017. The key factor driving the current global RBO market includes its diversified application, various cooking benefits as compared to other edible oils, growing health consciousness, aggressive manufacturer's promotion and increasing acceptance level in developed and emerging markets [46].

## 3.3. EXTRACTION OF RICE BRAN OIL

Rice bran oil can be extracted mechanically by pressing or chemically through solid-liquid extraction process [48]. Several methods used for the extraction of RBO include solvent extraction, mechanical pressing, supercritical and subcritical extraction, enzymatic-assisted aqueous extraction, ultrasound-assisted extraction, Soxhlet extraction etc. Among these methods, solvent extraction is the most popular for commercial RBO extraction and very effective because it can generally remove the very high amount of oil [49]. Hexane is the most commonly used solvent for the solvent extraction, and it proved to be efficient and relatively cheap [50]. In the solvent extraction process, the stabilised rice bran is directly mixed with solvent at about 20°C with rice bran to solvent ratio of 1:2 w/w. The solvent is evaporated after extraction to obtain the crude rice bran oil [51]. With solvent extraction method, RBO yield of about 92% and 99% were reported [13, 34]. Generally, crude RBO obtained through solvent or other extraction methods undergoes chemical or physical refining process to obtain a refined RBO which meet the specification for food grade edible oil [52]. A typical flowchart for solvent extraction and refining of RBO is shown in Figure 3.

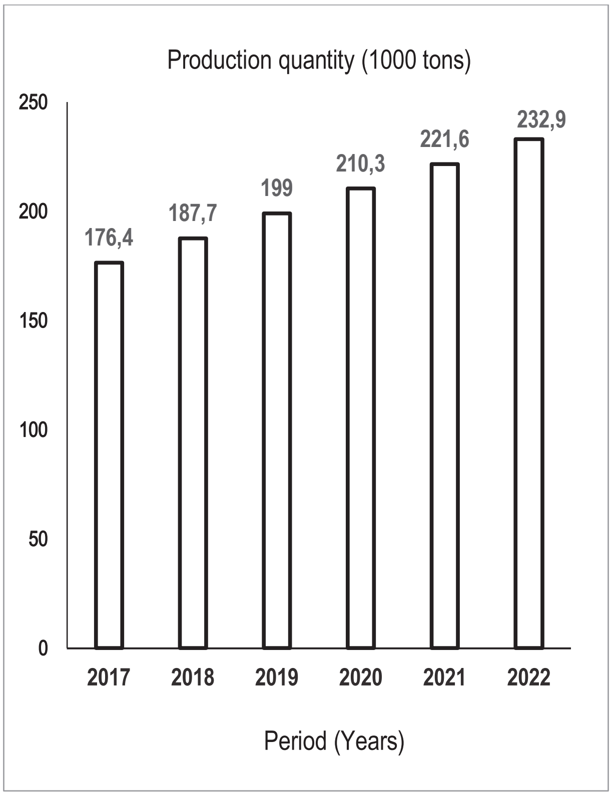


**Figure 2 -** World: Rice Bran Oil Market Forecast: Production Volume Trends (in '000 tons) 2017-2022
Source: [42]

## 3.4. USES OF RICE BRAN OIL

In many Asian countries like Japan, China, Korea, Taiwan and Thailand, RBO is considered as a premium edible oil, and popularly known as 'Heart oil' in Japan [43]. It is the best quality cooking oil because of its good cooking quality, fatty acids profile and shelf life [53]. RBO is stable at high temperature due to its high smoke point making it better for high temperature cooking like deep and stirfrying [53, 54]. it also gives better taste and flavour when used for cooking [55]. RBO has recently been used commercially in snacks industries and restaurants [56]. It has also been used as alternative shortening for bread baking, muffins, mayonnaise and salad dressing [55]. The rich phytochemical composition of RBO has made it an important ingredient in cosmetic and personal care industries. It has been used to produce sunscreen lotions, lipsticks, hair conditioners and nail polishes [57]. In pharmaceutical industries, RBO has been used as a supplement for bodybuilders and athletes for muscle development [30]. Administration of RBO has been shown to lower cholesterol level in

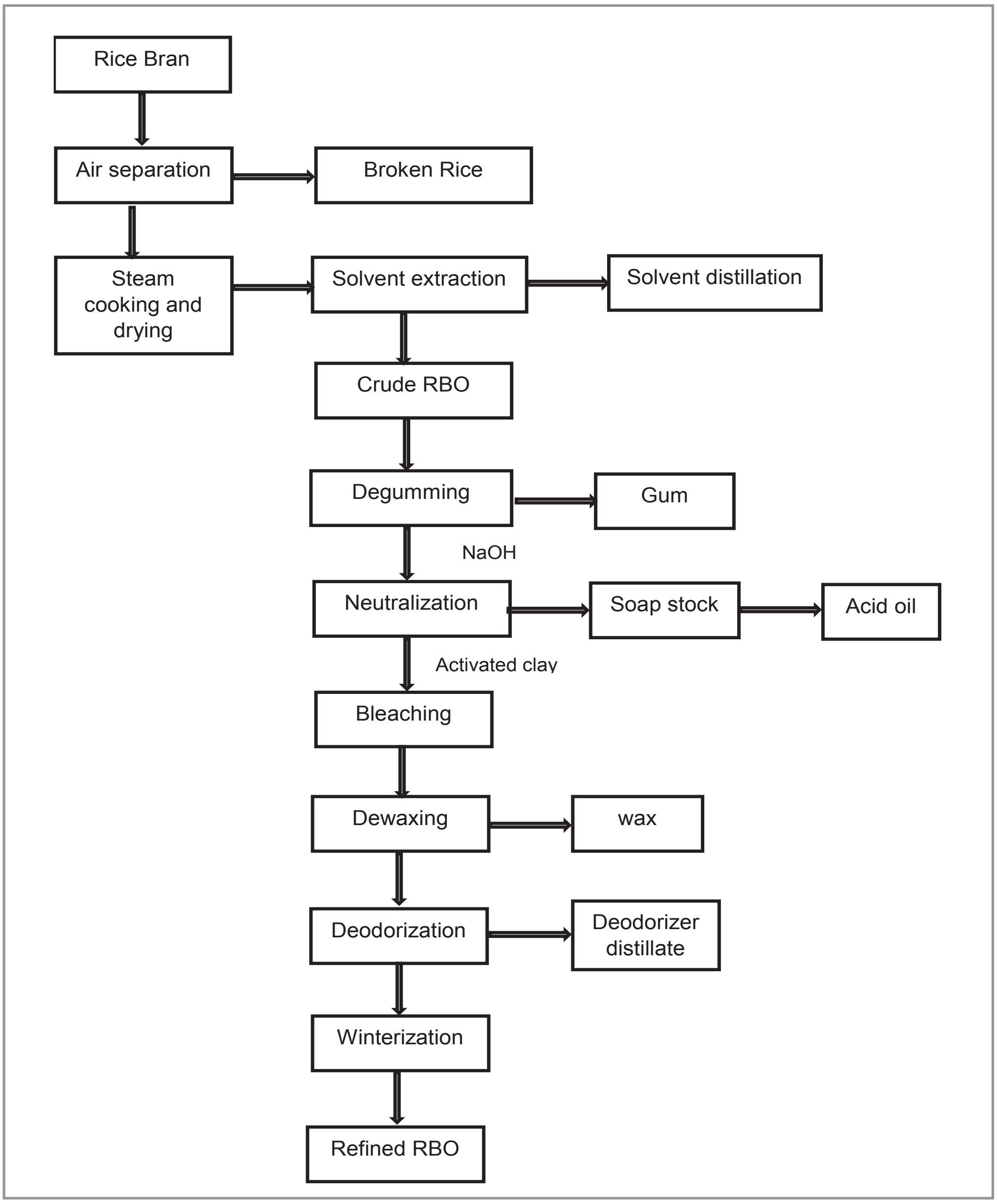


**Figure 3 -** Flowchart for extraction and refining of RBO

both human and animal to an appreciable level [58, 59]. Figure 4 shows the various health benefits of the phytochemicals present in RBO. Many by-products such as soapstock, deodoriser distillate and wet gum obtained during RBO refining are also useful for the extraction of phytochemicals such as gamma-oryzanol, tocopherols, tocotrienol, phytosterol, squalene and phospholipids for various nutraceutical and cosmetics applications.

## 3.5. COMPARABILITY OF RICE BRAN OIL AND OTHER VEGETABLE OILS

In contrast to most vegetable oils, RBO is not extracted from seeds or nuts as in the case of soybean or groundnut oil, respectively. It is obtained from the rice bran, a by-product of the rice grain milling process. Recently, scientific interest about RBO has emerged, compared to major edible vegetable oils. This is evidenced by the increasing number of articles published on RBO. However, even though the number may still appear to be low, the interest of the scientific community in studying RBO for its health benefits is growing due to its chemopreventive agents. This unique quality makes it useful for the treatment of several health disorders. Moreover, the characterisation of bioactive constituents of RBO, have led to a more concerted effort in the development of new pharmaceutical dosage forms of, or foods containing, rice bran oil or its constituents [60]. The major fatty acids composition of RBO in comparison to other major vegetable oils is presented in Table V. The composition of RBO is comparable to

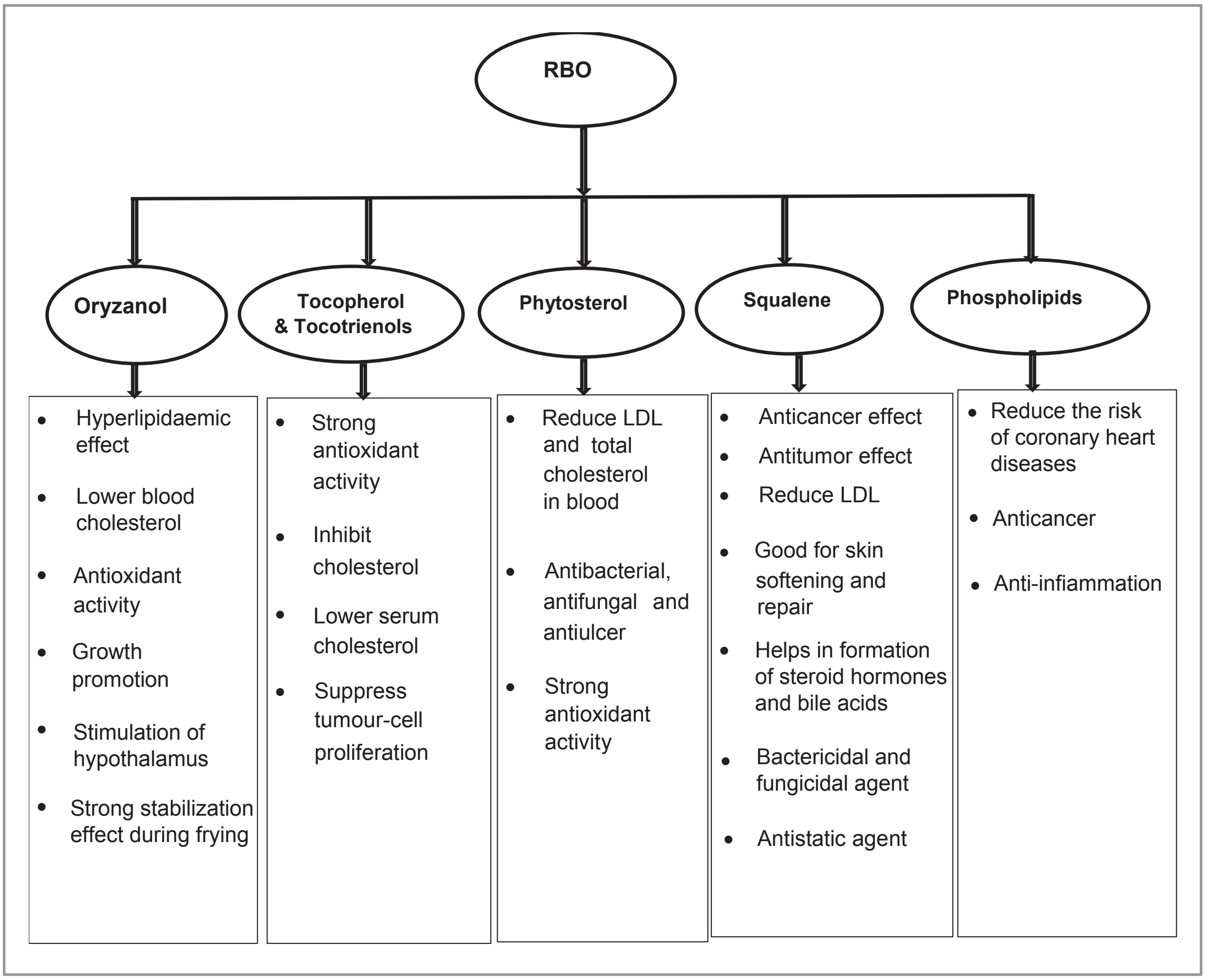


**Figure 4 -** Health benefits of some RBO phytochemicals



other vegetable oils with high levels of neutral lipids and smaller amounts of glycolipids and phospholipids. In contrast to other vegetable oils, the fatty acid profile of RBO tends to be higher in oleic acid and lower in linoleic acid which is identical to peanut oil [36]. As compared to other edible oils, the ideal ratio of SF/MUFA/PUFA in RBO is closer to the recommendation by WHO. WHO recommended a near equal ratio of SFA (27-33%); MUFA (33-40%) and PUFA (27-33%) in a healthy oil. Rice Bran oil is much closer to this recommendation having SFA (24%); MUFA (42%); PUFA (34%) [23].

**Table V -** Fatty acid composition (% total lipids) of RBO in comparison with other vegetable oils

| Fatty acids | RBO | Corn | Peanuts | Cottonseed |
|---|---|---|---|---|
| Myristic (14:0) | 1 | 0 | 0 | 0 |
| Palmitic (16:0) | 15 | 8 | 7 | 8 |
| Stearic (18:0) | 2 | 4 | 4 | 4 |
| Oleic (18:1) | 45 | 46 | 62 | 28 |
| Linoleic (18:2) | 35 | 42 | 23 | 54 |
| Linolenic (18:3) | 1 | 0 | 0 | 5 |
| Arachidic (20:0) | 0 | 0 | 0 | 0 |

Source: [36]

## 3.6. RICE BRAN OIL AND ITS POTENTIALS IN NIGERIA

In Nigeria, palm oil and palm kernel oil (80% and 20%), and soybean oil are the major supply sources contributing about 70% and 25% of the total national consumption requirement for edible oil. The country's local production of the edible oil reached 1.8 million tons per year [61]. The current demand and consumption of palm oil, peanut and soybean oil in Nigeria is 1.15 million, 0.263 million and 63,000 tons respectively, in 2017. On the other hand, the production in 2017 - 2018 of palm oil, peanut oil and soybean are at 970,000; 265,000; and 49,000 tons respectively [62]. In 2013, soybean oil has contributed 20% of the total of 2.4 million tons of the oilseed/vegetable oil demand in Nigeria [61]. Since 2010, Nigeria's palm oil production growth rate drops from 14.25 to 0.00% in 2018 [62]. The production deficit remained at a high rate of 600,000 tons per year [62].

Based on current Nigeria's rice production in 2017 and the estimated rice bran potential, an RBO potential of about 55,000 to 122,000 tons of RBO could be achieved. If this potential is fully exploited, it will help reduce the current deficit in edible oil demand and as well as reduce the oil importation.

RBO has the potential to complement the current Nigerian edible oil deficit. About 63 to 76 million tons of rice bran is produced annually in the world, and Nigeria contributes with about 400,000 tons. However, more than 90% of the rice bran produced in Nigeria is sold as poultry, livestock or waste [63]. An estimated 30,000 tons of rice bran is produced locally as a by-product, in which about 3300 tons is wasted yearly [26]. At present, there is no available commercial RBO extraction plant to trap this potential. Thus, to cover the deficit between the consumption, and production and importation of edible oil, industries for RBO can be established around the largest rice milling factories in the Northern region (Kebbi, Kano, Nasarawa, Niger and Gombe), West (Ogun, Lagos) and Southern region of Nigeria (Ebonyi, Anambra, Ekiti, Enugu).

## 3.7. CHALLENGES FOR SETTING UP RBO EXTRACTION PLANT IN NIGERIA

Some of the potential challenges that may be encountered when establishing RBO business in Nigeria are discussed in various headings below. The knowledge of these challenges will help the investors and the government to take pro-active measure for successful investment into the RBO business.

### 3.7.1. Insufficient rice bran production

Many of the rice mills in Nigeria are suffering from shortages of national electricity supply, lack of capital, input raw paddy and spare parts, as well as the problem of high bank interest rate. Lack of skilled labour are also the causes of considerable problems for operation and maintenance of the rice milling machinery. These are the major reasons why some fully integrated rice milling industries operate only a few months in a year with full capacity or several months in a year with one-third or half of their full capacity [18]. For sustainable RBO business, a continuous supply of adequate rice bran is required for the extraction plants. However, the above-mentioned constraints may contribute to an insufficient production of the bran that will ultimately affect the production of RBO.

### 3.7.2. Sourcing rice bran

Nigeria's rice sector is still driven mostly by cottage/small mills running with obsolete rice mills and mostly employs traditional processing methods [64]. Most of the small and medium-sized rice mills are scattered to various locations, thus, it will be difficult to transport fresh bran to the extraction plant within a shortest possible time [65]. The quality of rice bran depends on the free fatty acid contents. The lipase enzyme in the rice bran tends to hydrolyse the oil content into free fatty acids and glycerol. This, in turn, reduces the quality of rice bran, producing a foul smell and bitter taste due to rancidity and as well adversely affected the quality of oil [66]. These may be one of the difficulties in RBO production. However, with the current agricultural transformation (particularly in rice production), there has been an increase in the number of large-scale commercial rice processing industries in Nigeria (Tab. III). Thus, there is now an exciting potential for the RBO business.

**Table III -** Phytochemical composition of RBO

| Phytochemicals (%) | Crude RBO | Refine RBO | References |
|---|---|---|---|
| Gamma-Oryzanol | 1.5-4.4 | 0.19-0.20 | [70] |
| Tocopherols | 2-4 | 0.48-0.7 | [38, 71] |
| Tocotrienols | 0.007 | - | [35] |
| Phytosterol | 1.36-1.38 | 0.86-1.03 | [72] |
| β-sitosterol | 0.885 | - | [35] |
| Stigmayusterol | 0.27 | - | [35] |
| Campesterol | 0.051 | - | [35] |
| Squalene | 0.32 | - | [23] |
| Phospholipids | 1.2-1.9 | - | [37] |
| Waxes | 3.0 | - | [35] |

### 3.7.3. Transportation

The free fatty acid content (FFA) of the rice bran increases rapidly if not handled properly due to the activity of lipase enzyme on the oil [67]. The rate of oil hydrolysis by this enzyme is so high, that the FFA in the oil may increase by 10 to 20% in a day, and could further rise to 70% in a month. These changes in FFA may impart an undesirable dark colour to the oil [10]. After 2-3 days of storage, the acidity of the oil may increase to 10% during the first hours. It could rise up to 1% per hour [67]. Therefore, the rice bran needs to be transported to the oil extraction plants immediately after milling. This may rarely be possible due to the distance between the solvent extraction plant and the milling plants. Therefore, if proper care is not taken, the bran may deteriorate leading to a lower yield and poor quality RBO. This problem can be overcome by stabilising the bran through various stabilisation methods such as steaming or hot air heating [68]. For example, heating at 90-100°C and drying can arrest the activities of lipase and allow for storage and transportation [67].

### 3.7.4. Marketing challenges

The current purchasing power of the Nigerian population is very low [69]. This, coupled with the lack of awareness about the RBO and its numerous health and cooking benefits, will be a major concern when introducing the RBO as a new cooking oil into the Nigerian market. Such challenges can be overcome through intensive media advertisement and promotion, and involvements of a professional organisation such as Nutrition Society of Nigeria (NSN), Nigerian Institute of Food Science and Technology (NIFST) and other related organisations.

## 4. PROSPECTS OF RBO IN NIGERIA

Globally, the increasing consumer awareness and health consciousness that edible oils reduce cholesterol levels and an increase of personal care and cosmetic industries are likely to support the growth of the RBO market up to 2023. Establishment of International Association of rice bran oil (IABRO) in 2013 has greatly helped to promote the awareness on the health-related benefits of RBO among consumers, academics and health professionals across the globe [45]. With the establishment of RBO industries in Nigeria, many other opportunities such as lecithin (phospholipids) extraction, γ-oryzanol extraction, tocopherols, and tocotrienols etc., can also exist. The information in this paper will be very useful in recommending the establishment of RBO extraction plants in Nigeria by both indigenous and foreign investors.

## 5. CONCLUSION

Vegetable oils are an indispensable part of the human diet with a myriad of nutritional and health benefits. Several nonconventional sources of vegetable oils such as rice bran are expected to fill in the gap in demands and provide more benefits to the consumers. In Nigeria, an enormous potential exists for establishing RBO extraction plants especially in the Northern part of the country where rice is mainly grown. The utilisation of rice bran for edible oil extraction will potentially add value to the Nigerian rice milling sector. The major challenge associated with the rice bran is the rapid deterioration if not immediately stabilised. This may pose a great challenge for sourcing the raw material (bran) especially if transportation does not take place immediately to the extraction plant after milling. In addition, the lack of awareness on the health benefit of the oil coupled with its relatively high cost in comparison to other vegetable oils may be a challenge in RBO marketing and acceptability across the Nigerian edible oil consumers. At present, little or no information on the status of the rice bran from the milling industries is available and there is not enough data on the total quantity of bran produce across the country. Further studies may be required for cost analysis for the establishment of this industry.

**Conflict of interest**
The authors declare that there is no conflict of interest.

## REFERENCES

[1] V. Vucic, J. Tepsic, A. Arsic, T. Popovic, J. Debeljak-Martacic, M. Glibetic, Fatty acid content of vegetable oils and assessment of their consumption in Serbia. Acta Aliment, *41*, 343-350 (2012)

[2] R. Yang, L. Zhang, P. Li, L. Yu, J. Mao, X. Wang, Q. Zhang, A review of chemical composition and nutritional properties of minor vegetable oils in China. Trends in Food Sci. Technol. *74*, 26-32 (2018)

[3] Statista, Global production of vegetable oils from 2000/01 to 2017/18 (in million metric tons). Accessed on 07 July 2018. Available from: https://www.statista.com/statistics/263978/global-vegetable-oil-production-since-2000-2001/2018/07/16 (2018)

[4] FAOSTAT, Food Balance Sheets; Nigeria. Accessed on 10 July 2018. Available from: http://www.fao.org/faostat/en/#data/FBS/report/2018/07/10 (2018)

[5] R. Tabaraki, A. Nateghi, Optimization of ultrasonic-assisted extraction of natural antioxidants from rice bran using response surface methodology. Ultrason Sonochem. *18*, 1279-1286 (2011)

[6] A.S. Ajala, A. Gana, Analysis of challenges facing rice processing in Nigeria. J. Food Proc. *2015*, 1-6 (2015)

[7] V. Krishna, S. Kuriakose, A. Rawson, Ultrasound assisted extraction of oil from rice bran: A response surface methodology approach. J. Food Proc. Technol. *6*, 1-7 (2015)

[8] M. Sohail, A. Rakha, M.S. Butt, M.J. Iqbal, S. Rashid, Rice bran nutraceutics: A comprehensive review. Crit. Rev. Food Sci. Nutr. *57*, 3771-3780 (2017)

[9] A. Rohman, Rice bran oil's role in health and cooking. In: Watson, R.R., Preedy, V.R., Zibadi, S. (eds) Wheat and rice in disease prevention and health: benefits, risks and mechanisms of whole grains in health promotion. Elsevier, Academic Press, 481-90 (2014)

[10] R. Kusum, H.P.F.P. Bommayya, H.D. Ramachandran, Palm oil and rice bran oil: Current status and future prospects. Int. J. Plant Physiol. Biochem. *3*,125-132 (2011)

[11] K. Tomita, S. Machmudah, Wahyudiono, R. Fukuzato, H. Kanda, A.T. Quitain, M. Sasaki, M. Goto. Extraction of rice bran oil by supercritical carbon dioxide and solubility consideration. Sep. Purif. Tech. *125*, 319-325 (2014)

[12] P. Lai, K.Y. Li, S. Lu, H.H. Chen. Phytochemicals and antioxidant properties of solvent extracts from Japonica rice bran, Food Chem. *117*, 538-544 (2009)

[13] R. Oliveira, V. Oliveira, K.K. Aracava, C.E.D.C. Rodrigues, Effects of the extraction conditions on the yield and composition of rice bran oil extracted with ethanol - A response surface approach. Food Bioprod. Proc. *90*, 22-31 (2012)

[14] Index Mundi, Nigeria Milled Rice Production by Year. Accessed on 10 July 2018. Available from: https://www.indexmundi.com/agriculture/?country=ng&commodity=-milled-rice&graph=production (2018)

[15] J. Udemeze, *Oryza Sativa* (Rice). Master thesis, Department of Crop Science, University of Nigeria, Nsukka (2008)

[16] A.O. Oko, B.E. Ubi, A.A. Efisue, A Comparative Study on Local and Newly Introduced Rice Varieties in Ebonyi State of Nigeria based on Selected Agronomic Characteristics. Int. J. Agric. For. *2*, 11-17 (2012)

[17] [17] N. Danbaba, I. Nkama, J. Manful, N. Michael, M. Amaka, M.H. Badau, Physical and processing characteristics of some popular rice varieties in Nigeria. Int. J. App. Res. Tech. *2*, 64-73 (2015)

[18] V. Tan, Assessment of processing efficiency of SME rice mills in Nigeria. Accessed on 10 February 2018. Available from: http://cari-project.org/wp-content/uploads/2015/03/Processing-efficiency-of-SME-rice-mills_executive-summary.pdf (2016)

[19] R. Scott, U. Nzeka, J. Taylor, Nigeria's Grain Prospects and Challenges to Food Security. Lagos (2017)

[20] S. Muthayya, J.D. Sugimoto, S. Montgomery, G.F. Maberly, An overview of global rice production, supply, trade, and consumption. Ann. N Y Acad. Sci. 324, 7-14 (2014)

[21] FEWS, NET, Nigeria Market Monitoring Bulletin. Accesses on 10 February 2018. Available from: fews.net/sites/default/files/documents/reports/NMMB_12042017_final_4.pdf. (2017)

[22] J. Zúñiga-Diaz, E. Reyes-Dorantes, A. Quinto-Hernandez, J. Porcayo-Calderon, J.G. Gonzalez-Rodriguez, L. Martinez-Gomez, Oil extraction from "Morelos Rice" bran: Kinetics and raw oil stability. J. Chem., 1-9, (2017)

[23] V. Pali, Rice Bran Oil-Unique Gift of Nature: A Review. Agric. rev. 34, 288-294 (2013)

[24] S. Ea, M. Sardarodiyan, Bioactive phytochemicals in rice bran: Processing and functional properties. Biochemi. Ind. J. *10*, 1-10 (2016)

[25] E.I. Bello, O.O. Oluboba, Rice bran oil biodiesel. Eur. J. Eng. Tech. *2*, 59-69 (2014)

[26] O.I. Oluremi, A.O. Solomon, A.A. Saheed, Fatty acids, metal composition and physico-chemical parameters of Igbemo Ekiti rice bran oil. J. Environ. Chem. Ecotoxicol. *5*, 39-46 (2013)

[27] A. Roberts, E. Solomon, M. Lobâo, Rice bran: Potential feed for fish, poultry. The National, 5-9 (2016)

[28] S. Aparecida, C. Faria, P.Z. Bassinello, Nutritional composition of rice bran submitted to different stabilization procedures. Braz. J. Pharm. Sci. *48*, 652-657 (2012)

[29] P.M.N. Nagendra, K.R. Sanjay, K.M. Shravya, M.N. Vismaya, Nanjunda, S.S. Health benefit of rice bran- A review. J. Nutr. Food Sci. *1*, 1-3 (2011)

[30] B.M.W.P.K. Amarasinghe, M.P.M. Kumarasiri, N.C. Gangodavilage, Effect of method of stabilization on aqueous extraction of rice bran oil. Food Bioprod. Proc. *87*, 108-114 (2009)

[31] P. Loypimai, A. Moongngarm, P. Chottanom, Impact of stabilization and extraction methods on chemical quality and bioactive compounds of rice bran oil. Em. J. Food Agric. *27*, 849-856 (2015)

[32] S.S. Patil, A. Kar, D. Mohapatra, Stabilization of rice bran using microwave: Process optimization and storage studies. Food Bioprod. Proc. *99*, 204-211 (2016)

[33] O. Pourali, F. Salak Asghari, H. Yoshida, Simultaneous rice bran oil stabilization and extraction using sub-critical water medium. J. Food Eng. *95*, 510-516 (2009)

[34] N.R. Lakkakula, M. Lima, T. Walker, Rice bran stabilization and rice bran oil extraction using ohmic heating. Biores. Technol. *92*, 157-161 (2004)

[35] B.N. Rao, Nutritive value of rice bran. Nutrition Foundation of India Bulletin *21*, 5-7 (2000)

[36] J.S. Godber, In: R.A. Moreau, A. Kamal-Eldin. (Ed.) Gourmet and Health Promoting Specialty Oil. AOCS Press, Urbana, IL, (USA), 388-390, (2009).

[37] G.A. Nayik, K. Muzaffar, Future Edible Oil of India: Rice Bran Oil - "The Wonder Oil." SM J. Food Nutr. Disord. *1*, 2-4 (2015)

[38] D. Sanghi, R. Tiwle, A review of comparative study of rice bran oil and rice bran wax. Int. J. Pharm. Rev. Res. *5*, 403-410 (2015)

[39] A. Astrup, J. Dyerberg, The role of reducing intakes of saturated fat in the prevention of cardiovascular disease: where does the evidence stand in 2010?. Am. J. Clin. Nutr. *93,* 684-688 (2011).

[40] G. Tarantino, C. Finelli, Lipids, low-grade chronic inflammation and NAFLD: A ménage à trois? Handb. Lipids Hum. Funct. Fat. Acids. 731-759 (2015).

[41] N. Kaur, V. Chugh, A.K. Gupta, Essential fatty

acids as functional components of foods- a review, J. Food Sci. Technol. *51*, 2289-2303 (2012).
[42] K. Gul, B. Yousuf, A.K. Singh, P. Singh, A.A. Wani, Rice bran: Nutritional values and its emerging potential for development of functional food - A review, Bioact. Carbohydrates Diet. Fibre. *6*, 24-30 (2015).
[43] G.A. Nayik, I. Majid, A. Gull, K. Muzaffar, Rice bran oil, the future edible oil of India: A mini Review. Rice Res. *3*, 4-6 (2015)
[44] M.J. Lerma-García, J.M. Herrero-Martínez, E.F. Simó-Alfonso, C.R.B. Mendonça, G. Ramis-Ramos, Composition, industrial processing and applications of rice bran γ-oryzanol, Food Chem. *115*, 389-404 (2009).
[45] Global Market Insight, Rice bran oil market size, industry outlook report, regional analysis (U.S., Germany, UK, Italy, Russia, China, India, Japan, South Korea, Brazil, Mexico, Saudi Arabia, UAE, South Africa), downstream application development, price trends, competitive mark. Accessed on 6 September 2018. Available from: https://www.gminsights.com/industry-analysis/rice-bran-oil-market (2016)
[46] IMARC Group, Rice Bran Oil Market Share, Size, Price Trends, Growth and Forecast 2018-2023. Accessed on 6 September 2018. Available from: https://www.imarcgroup.com/rice-bran-oil-processing-plant (2018)
[47] IMARC Analysis, Global industry trends, share, size, growth, opportunity and forecast 20172022. Accessed on 6 September 2018. Available from: http://www.imarcgroup.com/ricebranoilmarket (2016)
[48] F. Javed, S.W. Ahmad, A. Rehman, S. Zafar, S.R, Malik, Recovery of rice bran oil using solid-liquid extraction technique. J. Food Proc. Eng. *38*, 357-362 (2015)
[49] W. Kong, Q. Kang, W. Feng, T. Tan, Improving the solvent-extraction process of rice bran oil. Chem. Eng. Res. Des. *104*, 1-10 (2015)
[50] D. Spark, R. Hernandez, M. Zappi, D. Blackwell, T. Fleming, Extraction of rice bran oil using supercritical carbon dioxide and propane. JAOCS. *83*, 10-16 (2006)
[51] R. Sharma, T. Srivastava, D.C. Saxena, Studies on Rice Bran and its benefits- A Review. Int. J. Eng. Res. Appl. *5*,107-112 (2015)
[52] [52] M. Patel, Naik, S.N, Gamma-oryzanol from rice bran oil - A review. J. Sci. Ind. Res. *63*, 569-578 (2004)
[53] H.Y. Fan, M.S. Sharifudin, M. Hasmadi, H.M. Chew, Frying stability of rice bran oil and palm olein. Int. Food Res. J. *20*, 403-407 (2013)
[54] A. Mariod, M. Ismail, N.F.A. Rahman, B. Matthaus, Stability of rice bran oil extracted by SFE and soxhlet methods during accelerated shelf-life storage. Grasas Aceites *65*, 1-10 (2014)
[55] A. Kaur, V. Jassal, S.S. Thind, P. Aggarwal, Rice bran oil an alternate bakery shortening. J. Food Sci. Tech. *49*, 110-114 (2012)
[56] D. Guzman, Health benefits strengthen rice bran oil use. Chem. Mark. Rep. *263*, 12 (2003)
[57] D.S. Bernardi, T.A. Pereira, N.R. Maciel, J. Bortoloto, G.S. Viera, G.C. Oliveira, PA. Rocha-Filho, Formation and stability of oil-in-water nanoemulsions containing rice bran oil: in vitro and in vivo assessments. J. Nanobiotech. *9*, 1-9 (2011)
[58] Y.H. Ju, S.R. Vali, Rice bran oil as a potential resource for biodiesel: A review. J. Sci. Ind. 8Res. *64*, 866-882 (2005)
[59] M. Joshi, R. Kaur, P. Kanwar, G. Dhiman, S. Lata, K. Tilak, N. Gupta, T. Mishra, To evaluate antioxidant activity of γ–oryzanol extracted from rice bran oil. International J. Life Sci. Pharma Res. *6*, 17-25 (2016)
[60] L.A. Rigo, A.R. Pohlmann, S.S. Guterres, R.C. Ruver Beck, Rice Bran Oil. Benefits to Health and Applications in Pharmaceutical Formulations, Academic press, Elsevier, 311-322 (2014).
[61] U.M. Nzeka, Nigeria Provides Export Market for Oilseeds and Products. GAIN Report, USDA Foreign Agric. Service (2014)
[62] Index Mundi, Nigeria Palm Oil Production by Year. Accessed on 7 September 2018. Available from: https://www.indexmundi.com/agriculture/?country=ng&commodity=palmoil&graph=production
[63] GRICD. Rice Bran Oil Production: Affordable solution to oil importation in Nigeria. Accessed on 7 September 2018. Available from: http://www.gricd.com/?p=22 (2016)
[64] R. Scott, U. Nzeka, J. Taylor, Nigeria's Grain Prospects and Challenges to Food Security. Lagos, (2017)
[65] A. Chakraverty, R.P. Singh, Postharvest Technology and Food Process Engineering. CRC Press (2014)
[66] R. Sharma, T. Srivastava, D.C. Saxena, Studies on Rice Bran and its benefits- A Review. Int. J. Eng. Res. Appl. *5*,107-112 (2015)
[67] W. Hamm, R.J. Hamilton, G. Calliauw, Edible Oil Processing. 2nd Edition, John Wiley & Sons Ltd, West Sussex, UK (2013)
[68] S.L. Chia, H.C. Boo, K. Muhamad, R. Sulaiman, F. Umanan, G.H. Chong, Effect of Subcritical Carbon Dioxide Extraction and Bran Stabilization Methods on Rice Bran Oil. *JOACS 92*, 393-402 (2015)
[69] FEWS NET. Famine early warning system network, Nigeria Market Monitoring Bulletin. Accessed 10 July 2018. Available from: fews.net/sites/default/files/documents/reports/

NMMB_12042017_final_4.pdf (2017)
[70] S.B. Ghatak, S.J. Panchal, Investigation of the immunomodulatory potential of oryzanol isolated from crude rice bran oil in experimental animal models. Phytother. Res. *26*, 1701-1708 (2012)
[71] A.G.G. Krishna, K.H. Hemakumar, S. Khatoon, Study on the composition of rice bran oil and its higher free fatty acids value. *JAOCS 83*, 117-120 (2006)
[72] P. Sawadikiat, P. Hongsprabhas, Phytosterols and γ-oryzanol in rice bran oils and distillates from physical refining process. Int. J. Food Sci. Tech. *49*, 2030-2036 (2014)
[73] G.A.I.N. Global Alliance for Improved Nutrion, Food fortification Initiative. Federal republic of Nigeria *663*, 1-15 (2016)
[74] N.S.M. Food, Quarra rice mil. Accessed on 18 August 2018. Available from: www.quarrarice.com/ (2013)
[75] D. Obi, Boost for local rice production as Amarwa rice mill, Kano, comes on stream. Business day. Accessed on 18 August 2018. Available from: nigerianbelgian.info/members/uploads/FileUpload/98/4524a.boost%20for%20local%20rice%20production%20as%20amarava%20rice%20mill,%20kano,%20comes%20on%20stream.pdf (2017)
[76] Nexon, Rice production in Nigeria. Accessed on 10 July 2018. Available at http://nextzon.com/wp-content/uploads/2017/10/Rice-Production-in-Nigeria.pdf
[77] FAOSTAT. Factfish, Nigeria: Rice, paddy, production quantity (tons). Accessed on 01 October 2018. Available from: www.factfish.com/statistic-country/nigeria/rice,+paddy,+production+quantity (2016)

*Received: August 19, 2018*
*Accepted: December 12, 2018*