

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

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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 role 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 its 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, Yargas 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 drying 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 lipoxigen-

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,

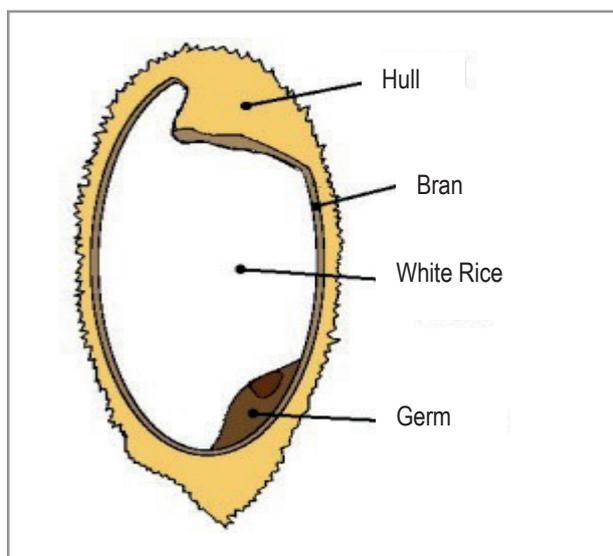


Figure 1 - Structure of rice grain
Source: [24]

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 γ -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

Lipid class	wt%	Fatty acids composition (%)							Saturated	Unsaturated
		Myristic	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Arachidic		
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 pro-

cess [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.

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

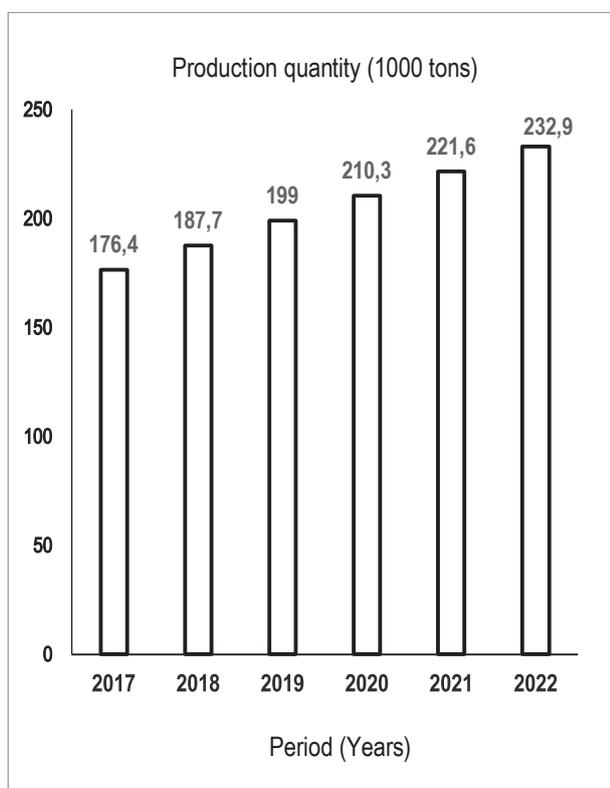


Figure 2 - World: Rice Bran Oil Market Forecast: Production Volume Trends (in '000 tons) 2017-2022

Source: [42]

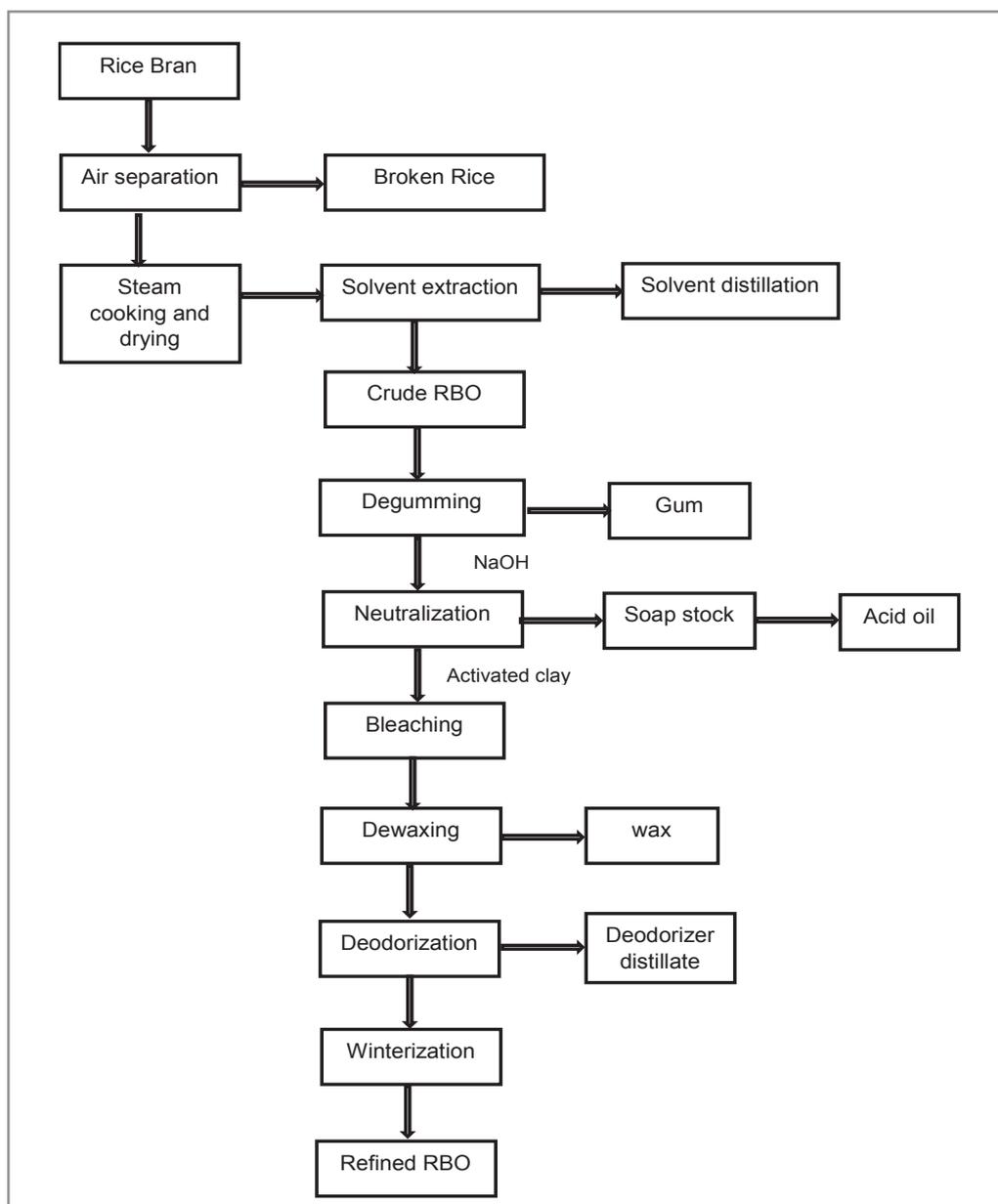


Figure 3 - Flowchart for extraction and refining of RBO

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

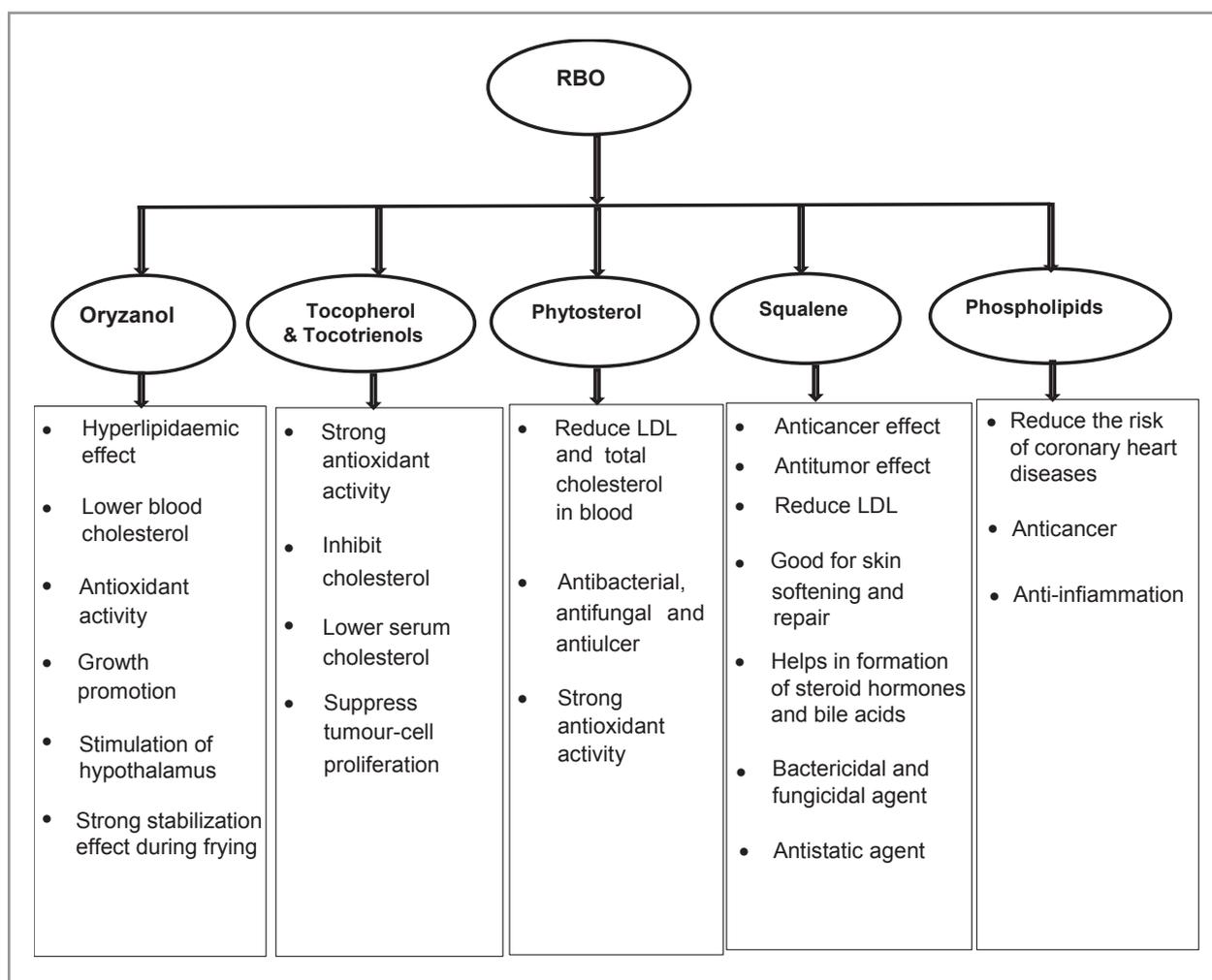


Figure 4 - Health benefits of some RBO phytochemicals

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].

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

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]

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]
Stigmasterol	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 popu-

lation 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.

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