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Short communication

Potential Utilization of Rubber Seed Meal as Feed and Food

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Abstract

Feed and food crisis has been a global concern due to its increasing prices. It led researchers to consider an alternative non-conventional edible material. This paper discussed the previous studies conducted on rubber seed as feed and food. *Rubber Tree (Hevea brasiliensis)* is a multipurpose tree; grown primarily for the production of latex with numerous useful by-products such as rubber seed, woods and oil. The rubber seed has a promising amount of crude protein, with the existence of a major toxic compound (cyanogenic compound) which has hindered the proper utilisation of the existing nutrient. The present review finds out the nutritional composition of the rubber seed to be moisture content was 3.99%, crude protein 23, crude fat 68.5 and ash 4.3 g/100g respectively. The amino acid in rubber seed was high in Glutamic acid (16.13%) and low in Cysteine (0.78%). Since, rubber seeds contained substantial amount proximate components, therefore it could be assumed as edible food and promising feed resource for livestock. Despite its promising protein contents, rubber seed meal contains cyanogens compound but this drawback could be overcome by boiling and storage time period which could lead to increase the nutrients availability and utilisation of rubber seed as edible feed and food.

Keywords: *Rubber seed; Feed; Food; Livestock.*

1. Introduction

Rubber seed is one of the vital biomass in the rubber tree's (*Hevea brasiliensis)* plantain. The rubber tree is known as a perennial cash crop, originated from South America and cultivated as an industrial crop since its introduction to the Southeast region around 1876 [1]. The main components of rubber tree are rubber seed and latex [2] whereas rubber seed contains 65% kernel and 35% shell [3]. Rubber tree yield can give an approximate amount of 150-250 kg of seeds per hectare [4]. However, it may depend on the soil nutrients, ecosystem of the located area, type of planting materials adopted and crop density [5]. The rubber tree is monetarily cultivated for the production of latex as a source of non-synthesize rubber for the production of different rubber products being used globally for industrial and domestic products [6]. The subsidiary resources derived from rubber plantations are a log of woods and seeds. The seed has numerous values both domestically and industrially [3]. The seeds are underutilized except when used as sources of seedlings [7]. Several researchers have reported that rubber seed meal has considerable amounts of absorbable nutrients than many conventional seed meals, and it exhibits high essential nutritive value as a better alternative for protein supplements in livestock diets [8, 9]. Some region in Indonesia even consumes processed rubber seed as part of their staple diet [10]. This paper, therefore, reviews the nutritional composition of rubber seed, its potential utilisation as edible feed, food and economic benefits of rubber plantation.

1.1. Description of Rubber Tree

Rubber tree belongs to the family of *Euphorbiaceae*. The ordered position of *Hevea brasiliensis* is shown in Table 1. The rubber tree is a fast-growing perennial crop, with an average height of 30 to 40 m with the profound and leafy crown. The trunk is structured in a cylindrical shape, straight greyish back and smooth surface. Rubber tree starts producing latex from 4 to 6 years through the structure compartment called laticiferous. Each tree produces around 800 to 1000 seeds (1.3 kg) twice in a year. The seed conceals of a thin hard shell and contains mute quantity oil for the industrial purpose [6]. The leaves are trifoliate and spiral in nature, 3 to 6 cm wide and 10 to 15 cm long. The trees are monoecious and the female apical flower is found in the panicles and numerous male lateral in the inflorescence [11].

1.2. Industrial Plantation of Rubber Tree

Over the century, rubber tree (*Hevea brasiliensis)* had been found mostly in Asia and Africa region whereas most of the plantation are predominantly found in Southeast Asia and West Africa. The global trend of rubber tree growing area received a rapid growth in the early 1990s. Nevertheless, the rapid growth in the rubber plantation subsequently encountered a decline in its expansion with time in several nations whereby rubber planting area covers approximately 11.5 million hectares of land around the globe [12].

Table 1: Classification of Rubber Tree.

Kingdom	Plantae
Plantae	*Magnoliophyta*
Class	*Magnoliosida*

Order	*Euphorbiales*
Family	*Euphorbiaceae*
Sub-family	*Crotonoideae*
Tribe	*Micrandreae*
Sub-tribe	*Heveinae*
Genus	*Hevea*
Species	*Brasiliensis*

Source: FAOSTAT [12]

Table 2 and Figure 1 shows the harvested areas, leading producing latex and rubber seed. Asia countries such as Indonesia, Thailand, and Malaysia engulf the largest harvested area of latex which are Indonesia, Thailand, and Malaysia have rubber plantation areas of nearly 3.63, 3.09, and 1.07, respectively while the least nations are Burma, Philippines and Cote d'Ivoire [12, 13, 14]. The Africa nations were led by Nigeria followed by other neighbouring West African nations [12].

Table 2: Harvested area of rubber plantation.

Country	Harvested Area (hectare)	Latex Production (kg/yr)	Estimated Seed Produced(t/yr)[a]
Indonesia	3,639,092	4,476,636	909,773
Thailand	3,093,971	3,157,780	773,493
Malaysia	1,072,920	673,513	268,230
China	718,060	811,344	179,500
Vietnam	621,370	1,035,333	155,343
India	454,044	952,806	113,511
Nigeria	377,733	156,341	94,433
Burma	293,000	221,670	73,250
Philippines	215,648	362,626	53,912
Cote d'Ivoire	189,937	310,655	47,484

Source : FAOSTAT [12]

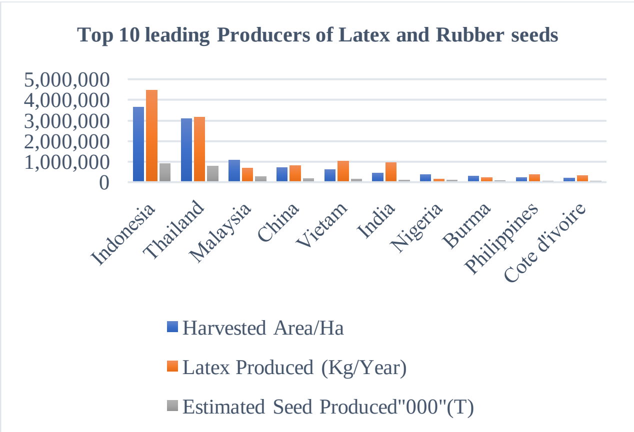

Fig. 1: Leading producers of latex and rubber seeds. Source: FAOSTAT [12].

The top five producers of rubber plantation led the global rubber agronomic activity and with the aggregate rubber plantation area of 78% across the worldwide rubber plantation land areas [12]. Figure 2 indicates the production trends of rubber plantation around the Asia nations. Thailand, China and Vietnam had tremendous growth in their rubber sector industrialization. FAOSTAT [12] reports that five Southeast Asia and three West Africa nation such as Vietnam, Philippine, Cambodia, Laos, Myanmar, Cote d'Ivoire, Ghana, and Cameroun shows immense concern and advancement in rubber industrialization since the last decade. Malaysia, which focuses on rubber planted region augmentation to 1.2 M ha by 2020 have introduced rubber replanting and new planting program. These hypothesised projects and vast development rubber industry are indications of the high potential of rubber biomass availability in the coming future [14].

Industrially, the major outputs extricated from the rubber tree are whitish fluid called "latex" and rubber seed [1]. Rubber seed is a vital biomass by-product which is presently deserted by most nations due to its limited literate level about its usage [15, 6]. The volume of rubber seeds produced has a direct relationship with rubber clones which have a close relationship with the tree age and size, while the height does not influence the production of rubber seed [15]. However, canopy cover is another related factor that has positive effects on the yield of rubber seed [16]. Data obtained from a study conducted at the Xishuangbanna province of China to estimate the rubber seed from the clones of Malaysia (RRIM600#) and Indonesia (GT1#) respectively represented the Southeast Asia region due to the clones that are mostly used in this region and the yield from this plantation was over 1500kg/ha [15]. Similarly, numerous studies have reported rubber seed yields, but these volumes were presumed through data retrieved from local farmers and government officials. Unfortunately, this situation led to underestimation and presumption of the yield of rubber seed production. The rubber seed yield ranges from 150 to 2000 kg/ha [16, 17, 18, 19, 20]. The average rubber seed yield was about 250kg/ha/year. Table 3 indicates the average estimate of rubber seed yield per hectare in the harvested areas of over 10 major producing nations.

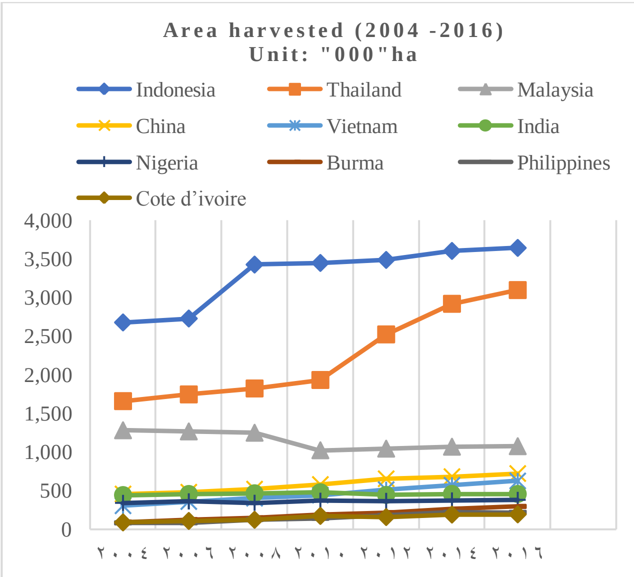

Fig. 2: Trends of harvested Area 2004 -2016. Source: FAOSTAT [12].

Table 3: Indicate the estimated rubber seeds and the counted value.

Country/Region	Estimated rubber seed yields	Year	References
Based on Estimated Value			
India	150/kg/ha/year	2010	[20, 23]
	160/kg/ha/year	2011	[24]
Malaysia	150/kg/ha/year	2010	[4]
Bangladesh	150/kg/ha/year	2011	[13]
China	1500-2000 /kg/ha/year	1999; 2005	[25, 26]
Based on the Counted value			
Xishuangbanna (South West China)	1553.19 kg/ha/year	2014	[16]

1.3. Economic Contribution of Rubber Tree Plantation

Rubber tree belongs to the perennial crop, which takes the period of 4 to 6 years to attain maturity. Before tapping the whitish fluid known as "Latex" which is extracted from the trunk of the tree on a daily routine. This plantation has numerous socioeconomic benefits to the ecosystem. It supports livelihood by providing multiple by-products for domestic and industrial purposes such as wood log which is commercially transformed into furniture and fibre [1, 21, 22]. On the other hand, rubber seeds are measurable biomass from rubber tree plantations are produced twice in a year. It has multiple by-products such as biodiesel production and industrial oil extraction for paint. The seeds are sources for animal feed and fertilizer production [6, 19].

2. Morphology of Rubber Seed

Seeds of rubber tree are large, slightly compressed, shiny, ovoid, 2 to 3.5 x 1.5 to 3.0 cm in shape, the weight about 2 to 4 g per seed, the outer shell is grey or pale brown with irregular dark brown dots, blotches and line. Capsule pressure determines the shapes of the seed. The endosperm is characterized by two visible colours whereby the whitish colour signifies the viability of seeds while the yellow colour could be found in the older seeds [27].

2.1. Nutritional Composition of Rubber Seed

Rubber seed is a biomass by-product of rubber plantation that has considerable qualities such as feed and food. Table 4, and 5 show the composition of rubber seed and amino acids from previous studies.

Table 4: Proximate analysis composition.

Authors	Moisture	Ash	Crude Protein	Crude Fat	Crude Fibre	NFE
Oyewusi et al.[28]	2.60	2.30	21.90	6.40	73.70	NG
Mmereole [29]	NG	3.10	34.10	10.12	4.40	NG
Eka et al. [19]	3.99	3.08	17.41	68.53	NG	6.99
Onwurah et al. [30]	3.90	2.60	22.30	42.50	NG	29.00
Sharma et al. [31]	16.00	0.24	25.40	39.10	75.00	33.20
Hossain et al. [32]	14.30	1.80	26.10	11.00	43.00	13.80
Suprayudi et al. [33]	1.50	3.14	21.87	49.30	3.19	21.00
Udo et al. [9]	3.09	3.77	23.31	38.47	5.88	NG
Aguibe et al.[8]	5.01	5.34	30.68	22.27	5.61	33.53
Lalabe et al. [34]	2.80	5.90	19.40	45.50	4.50	NG

NG: Not Given; NFE: Nitrogen Free Extract

Moisture content: The least moisture content of rubber seed is 1.5 to 2.8% (Table 4). The result is in close agreement with the earlier studies that reported on moisture content at 3.9%, 4.0%, and 5.8% respectively [18, 30, 35]. However, the result differs from the findings of Oyekunle and Omode at 9.0% [36], Oyewusi et al. at 14.1% [28] and 16 % by Sharma et al.[31]. It implies rubber seed meal with high moisture contents are probably more susceptible to microbial attack while longer shelf-life is assumed to be of low moisture content seed [18].

Total ash (TA): The total ash content of rubber seeds was <2.5% [31, 32] (Table 4). Most results fall within the range of 3- 5 % [8] [18, 34, 9] while the least result was reported as 0.24 % [31]. However, ash contents at <2.5 % have significant importance in compounding diets [37].

Crude fat: The crude fat content of rubber seeds in a recent concluded study was 45.50% according to Lalabe et al. [34] compared to 42.5% [30]. However, this result differs from other reports of 68.5 %, 49.3% and 38.47 % respectively [18, 9, 33]. Crude fat contents tend to improve digestibility and influence palatability of feed. The possible reason for the high crude fat content could be either due to variation in the proportion of kernel content of the seeds or preparation techniques of the rubber seed meal.

Table 5: Comparing Non- essential and essential amino acids in rubber seed protein with soya bean proteins.

	Non-essential amino acids (g/100g)		
	A	B	C
Aspartic	11.10	5.20	8.04
Serine	5.89	0.23	3.02
Glutamic acid	16.13	8.88	11.25
Glycine	5.14	2.04	4.01
Histidine	2.95	0.83	2.35
Arginine	12.45	0.22	5.11
Alanine	4.71	1.55	2.39
Proline	6.77	1.77	1.81
Cysteine	0.78	0.69	1.46
Tyrosine	2.88	1.51	3.38
	Essential amino acids (g/100g)		
	A	B	C
Thronine	3.72	0.59	2.33
Valine	7.08	2.16	3.83
Methionine	1.37	0.45	1.49
Lysine	4.26	2.03	4.99
Isoleusine	3.28	1.62	3.51
Leucine	6.81	2.81	7.19
Phenylalanine	4.88	2.06	4.90

Eka et al. [19] /Rubber seed meal (A)
Bujang & Taib [38]/ Soybean meal (B)
Oyewusi et al. [28]/ Rubber seed meal (C)

2.2. Anti-Nutritional Factors in Rubber Seed Meal

Anti-nutritional factors are common toxic content found in any edible plant part. It becomes a threat if the presence is above the safe margin for consumption, which leads to poor nutritive value. In addition, slow growth and hinders proper digestion can be resulted by anti-nutritional factors. The anti-nutritional factors might be described as those biological contents produced in edible feed/food contents which diminishes nutrient utilisation of edible food intake, thereafter contributes to impair gastrointestinal and metabolic performance which exert effects is contrary to ideal nutrition process [39]. Rubber seed has considerable high protein contents and also have numerous anti-nutritional factors such as hydrogen cyanide, phytic, oxalic, tannin, saponin, and trypsin inhibitor [8, 9, 18, 19, 31]. The cyanogen compound is more prominent in rubber seed. It has a direct effect on the amino acids of the body whereby when ingested, it might lead to imbalance amino acids. However, it has been reported that processing of the edible plant-based responses positively in diminishing the anti-nutritional factors. Storage of rubber seed for two months have been proven effective in diminishing the anti-nutritional factors but it not sufficient for nutritionists. Therefore, other approaches have been adopted to reduce the anti-nutritional factors to safety margin for consumption. Numerous studies had been conducted to examine the most effective methods, low cost and availability of materials to process the rubber seed such as storage, heat treatment, soaking, fermentation, enzymatic, fungi (mushroom), protein isolation and adsorbent (rice husk and wood ash) [8, 9. 28, 31, 40, 45].

2.3. Effects of Processing Rubber Seed

Cyanogen content is the most prominent content in rubber seed meal. Aguihe et al. [8] and Udo et al. [9] reports that raw rubber seed meal 315 mg/kg, and 249 mg/kg were lesser than the estimation recorded by Okafor and Anyawu [43] and Sharma et al. [31] as 391.60 and 415.10mg/kg respectively. In comparison, values were greater than the outcome from Batel et al. [44] and Eka et al. [19] as 263 and 186 mg/kg respectively. According to previous author JECFA [45], cyanogenic glycoside concentrations may differ due to hereditary, environmental factors, location, season, and soil factors. Numerous methods had been adopted for processing the rubber seed in order to improve the protein content and drastically diminish the levels of cyanogens content and other anti-nutritional factors. Heat treatment, fermentation and adsorbent had proven efficacy in reducing the cyanogens content [9, 8, 19]. These earlier reports were also in concurrence with Ukpekor et al. [46] Fortuna et al. [31] who affirms that heat treatment and fermentation have tendencies to lessen the convergence of cyanogens contents in rubber seed and improve the nutritional value simultaneously. However, Ogunka-Nnoka and Mepba [47] states that free and bound cyanide are water-soluble and might be leached out through boiling. The finding also corresponds with the description that anti-nutritional factors are heat liable [8, 9, 19].

Phytate is mostly found in edible plants and is responsible for the storage of minerals such as phosphorus. Phosphorous plays a significant role in the metabolism process. So if consume in mild quantity, it has a beneficial effect on the livestock and likewise vice versa if consumed beyond the livestock requirements. Most studies focus more on cyanogenic content in rubber seed leaving-out other anti-nutritional factors due to its little effects on growth and development of livestock. However, Udo et al. [9] report that phytate content ranged from 0.51, 0.33, and 0.26 in raw, toasted, and boiled respectively and the outcome of the processing technique signifies that boiled seeds had lower phytate. Similarly, the findings of the previous author range from 0.264 to 0.510 on the phytic content of rubber seed. The phytic content in rubber seed is lower than the value obtained which ranges from 0.682 to 0.719 from African yam bean [48] although more than 0.08 was revealed in another exploration about African yam bean [49]. The heat liable and fermentation techniques might be considered to be effective in the reduction of phytic content.

Oxalic acid is one of the anti-nutrients found in forage material. It can bind with dietary Magnesium (Mg) or calcium (Ca) to form insoluble Mg or Ca oxalate, which might lead to low serum Mg or Ca levels and to renal dysfunction due to the precipitation of these salts in the kidneys [50]. Monogastric are more prone to oxalic acid than ruminant animal due to it digestive physiological difference which harbours oxalate-degrading bacteria in the rumen which increases rapidly to prevent oxalate poisoning. However, the level of oxalate in rubber seed was reported as 0.12% in boiled, 0.14% in toasted to 0.18% in raw [9]. The availability of compound in both raw and processed rubber seeds shows that processing has little impact on lessening the substance of oxalate in rubber seed. The value of oxalate in both raw and processed rubber seeds are within the safe margin for consumption which is in line with the finding which states that < 0.5% are for monogastric [50].

Tannin is one of the anti-nutrient factor common in most cereal grains and legume seeds. Tannins bind proteins, thus impairs protein digestion metabolism [51]. Udo et al. [9] observe that the lowest tannin values in boiled seeds are (0.02), followed by toasted of (0.04), and while the raw one has a value of 0.07. The values obtained from processed rubber seeds are lower than other similar non-conventional feed such as *Mucuna pruriens* (0.80%)[52]. The outcome demonstrated that boiled seeds are better detoxified compared to raw and dry heat treatment (toasting) [9]. Boiling has been found to decrease the anti-nutritional factors and thereby enhance the nutritional value of feed [53]. The findings are similar to that of Ogundipe et al. [54], which discovers that 71.91 % tannin contents destroyed after 30 mins of boiling. In reference to the findings, heat treatment might be effective in detoxifying tannin compound.

The saponins are naturally occurring steroidal glycosides mainly produced by plants but also by lower aquatic animals and some bacteria [55, 56]. From biological value, saponin is mostly grouped as an anti-nutritional factor. Sometimes, it has physiological effects on the organism such as decreased feed intake, protein digestibility, inhibit the growth rate of monogastric and exhibit toxicological effects when measurable level saponin is found in diets. Various methods were adopted to detoxify the saponin in rubber seed meal. Saponin values for raw, boiled and toast were different after processing methods with a value of 0.42% (boiled), 0.56% (toasted) to 0.76% (raw). [9]. Saponin is related with the bitter taste and decreases the satisfactoriness of domesticated animal's feed. Since the saponin content of boiled and toasted is lower than the raw, it implies that the former has good detoxifying methods. Anya [48] acknowledged the fact that heat treatment is so efficient in diminishing saponin content.

Trypsin inhibitor records high value of (18.87%) in raw seed and zero value for the processed seeds [9]. Ononogbo, (1998) finding is contrary to the previous value. The outcome concurs with the report of Akinmutimi [52] who announces a 100% diminishment in trypsin inhibitor when subjected to heat treatments. Udo et al. [9] reveal that a 100% decrease in trypsin inhibitor infers that protein digestibility would not stop when heat treated seeds are fed to livestock. The differences in anti-nutritional factors were built upon several parameters, which might occur due to the ecological area of the seed, climatic condition, processing methods, genetic modifications, and storage these factors have influenced during the state of the seeds.

3. Utilization of Rubber Seed as Edible Food

The protein content of rubber seed can contribute to the human diet. The Estimated Average Requirement (EAR) in human for protein intake can be categorized into two such as; male 56 g (from 19 to >70 y) and female 46 g (from 14 to >70 y). Under the United States Department of Agriculture (2016), this daily requirement is based on a single intake of about 0.25 kg rubber seeds/day. The differences in the crude protein, as well as other proximate values from serial of studies, could be attributed to the differences in species of rubber trees, soil composition, climatic conditions as well as agricultural practices or low host mechanism meant for absorption of nitrogenous nutrients and inadequate fertilizer application of the rubber plantation [18].

Ash content indicates the quantity of inorganics content in the sample [36]. In the recent findings, the ash content is 5.90 g/0.1kg [34]. Serial of obtained value of ash content in rubber seed meal varies between 3.1 to 9.50 % [9, 29, 33]. The ash substance encompasses various kind of minerals that support growth and development. Numerous studies on the nutritional composition of rubber seed indicate that significant minerals do exist on raw rubber seed [9, 19, 36]. Some of these essential minerals are the Ca, Fe and Mg that support physiological development in the body. Oyekunle and Omode [36] reported that value of Ca (92.4×10^{-3} mg/g) and Fe (91.7×10^{-3} mg/g) while Ca (196×10^{-3} mg/g), and Fe (7.0×10^{-3} mg/g) [9].

Minerals are vital nutrients that the human body requires in minor quantities for optimal performance. In human, Calcium is needed for multiple physiological activities such as blood vessel contraction within the body, the movement of muscles, the secretion of numerous hormones and enzymes, and stimulates impulse through the central nervous system [58]. Iron (Fe) is a basic constituent of erythrocytes, and many enzymes while heart rhythm also utilizes magnesium for its activities, nerve function, and muscles. Rubber seed can contribute the mineral requirement for optimal growth.

The human body contains some basic composition, calcium occupies nearly 1.9% of the total body weight, and which can be ranked as the fifth position after oxygen, carbon, hydrogen, and nitrogen. For Calcium, the basic recommendation for daily intake is regarded as Adequate Intake (AI), originated from the National Academy of Sciences under the Institute of Medicine (IOM) [19]. Adequate Intake (AI) for both sex above eight years is 1.00 to 1.30 g/day [59]. With regards to the rubber seed composition, a 200 g serving of rubber seed can provide about 1.70 g calcium, which contributes 16% of Adequate Intake requirement [9]. United States directed the Food and Drug Administration (FDA) to indicate the inclusion rate on the label of food base on Daily Value (%DV) for iron (Fe). Food and Drug Administration structured a reference pattern to indicate the DVs that are present in a food product to enable customers to decide whether nourishment contains a considerable measure or inadequate needed nutrient. The DV per cent is the expression of nutrients gotten from one ration. National Institute of Health [60] stipulated DV for iron as 18 milligrams. A diet giving below 5% of the DV is a low source while nourishment that gives 10-19% of the DV is a good source. Nourishment that provides at least 20% of the DV is adequate in nutrients [19]. Hence, rubber seed is generally poor in some of the major minerals such as Calcium (Ca) and iron (Fe). Moreover, foods can exhibit lower value if AI or DV can also contribute to a healthful diet.

Rubber seed contains some essential amino acids, which are more imperative to sustainability, because the body cannot synthesise these amino acids, and they need to originate from food/feed or amino acid supplements. The amino acids are the prerequisite substances needed to support metabolic demands which also upholds appropriate body composition and growth rates. The dietary protein must contain satisfactory and digestible substances of nutritive value [61]. Oyewusi et al [28] reveals that amino acids of the processed rubber seed of the study indicate that rubber seed are moderate in glycine, valine, isoleucine, tyrosine and serine, low in alanine, histidine, threonine, proline, methionine and cysteine and high in glutamic acid, aspartic acid, leucine, arginine, lysine, and phenylalanine. The general pattern from the above findings closely concurs with the results of Eka et al. [19]. Aspartic and glutamic acids are the main amino acids in the processed rubber seed which make makes up of 0.20kg/kg of % protein [28]. These amino acids contributes to the palatability and taste characteristics of food, producing a sweet taste from alanine, glycine and threonine; MSG like taste from this group of aspartic and glutamic acid, bitter taste from this amino acid arginine, histidine, isoleucine, leucine, methionine, phenylalanine, tryptophan and valine; lysine and tyrosine contribute to the flat taste [62]. Eka et al. [18] report that rubber seed has a more bitter score of 38.82 from amino acid contents (38.82), 27.31 (MSG-like), 19.46 (sweet) and 7.14 (Flat).

Regardless of its possibility as a protein source of food, the existence of a poisonous substance, a cyanogenic compound in a rubber seed might be a drawback on its utilisation as an edible food source. Many findings had reported that raw rubber seeds contain 186 to 315g of hydrogen cyanide (HCN) per kg [8, 9, 40]. One of the viable means of reducing toxic content is the storage of a rubber seed at an ambient temperature of a minimum period of two to four months, heat technique, enzymatic reaction, absorbent and fermentation. This indicates that with an appropriate processing technique, rubber seed could be a good protein source because it contains an optimal amino acid profile that supports metabolism and proper growth.

3.1. Traditional Utilization of Rubber Seed as Food

Globally, rubber seed has limited literature about it utilization as edible food, but it was reported to have been utilized by Indians at Amazon Valley of South America, Indonesia [41]. Malaysia as well preserves the rubber seeds at some region in Sarawak by soaking it in salt water overnight, thereafter, kernels can be stir-fried with ikan billis and simultaneously served with rice, and other main dishes without adverse effects [42]. Rubber seed meal can be used as edible food due to nutritional requirements during the time of famine.

4. Utilization of Rubber Seed as Feed

From the perspective of the nutritive composition of rubber seed meal, it could be an optional replacement for conventional feedstuffs. It was reported to be excellent nitrogenous sources are the major constraint that impaired the proper development of livestock production in numerous tropical districts around the globe. The rubber seed with 11-35% crude protein is considered as an alternative protein supplement for livestock as shown in Table 1. Rubber seed is a vital biomass by-product of rubber plantation in several Southeast Asia and Western Africa nations, and it is incorporated as feed ingredients to monogastric, ruminants, and aquatic [19, 35, 63, 64] due to its abundance availability around the Asia and West Africa regions of the world. In terms of nutritional value, processed rubber seed meal contains a relatively high crude protein and lipid content of about 30.6% and 22.2% respectively [8] but rubber seed is known to have a high level of hydrocyanic acid (HCN) which could be minimized through storage and steam physical activity [9, 31, 33]. However, the cyanogen content of rubber seed oil can be eliminated using several methods like leaving the press cake as a promising source of alternative crude protein for livestock feed [65].

4.1. Traditional Utilization of Rubber Seed as Feed

Traditional utilisation of rubber seed meal as edible feed has increased in recent time. It was reported that local fishers utilise the rubber seed meal as baits for aquatic. Likewise the fodder was also used as a source of feed to the large ruminants [66]. However, researchers have carried different experiments trial on the utilisation of rubber seed meal as a replacement for conventional feed (soybean) on different classes of livestock. Firstly, the adoption of rubber seed meal was reported by Ong and Yeong [67] as a feeding trial on growth performance of pigs. The study observed poor growth rate on the usage of rubber seed meal above 20%. Similar studies were conducted on that same direction whereby findings of the earlier author were subsequently validated by Babatunde et al. [68]. The decline in growth rate from both studies can be due to the level of inclusion and presence of hydrogen cyanide which is known to be an inhibitor to feed consumption, hinder nutrients availability which results to decline growth, development and also deficiency lysine and methionine in the meal. On the contrary, Madubuike et al. [35] report that rubber seed meal could be utilized in swine production up to 10% of the dietary protein requirement without adversely affecting growth performance, and cost of production. However, recent findings indicate that the inclusion rate of rubber seed meal could go beyond 10% if appropriate processing technique is adopted for rubber seed [9, 31, 64]. Several researchers adopted some of the effective methods which lead to detoxification of cyanogen compounds of storage meant for a minimum of 2 months, heat treatment, soaking, fermentation and absorbent [8, 9, 33, 40]. These methods promote rubber seed utilisation, destroy the anti-nutritional factors, to increase palatability and proper utilisation of protein content in the meal [69].

Numerous studies reveal that rubber seed meal is a possible alternative when it comes to poultry feed production. Recently, a study conducted by Aguihe et al. [8] shows that 300 birds were raised for 42 days based on 30% rubber seed meal, during the period, the cooked and fermented records the best performance close to the control diet. Khatun et al. [70] findings are also concurrence with the earlier study of which recommends 10 to 20% of the unprocessed rubber seed meal which promotes increased feed conversion ratio and proper body development. Every diet has its influences on blood composition of the organism subjected to it. Mmereole [29] reported a decline in the blood indices parameters which are the mean corpuscular volume (MCV) and mean corpuscular haemoglobin concentration (MCHC) as more rubber seed meal was incorporated into the diets which might be due to the traces of anti-nutritional factors present in rubber seed meal. Mean corpuscular volume generally tends to increase as the proportion of rubber seed meal increases in the diets, obtaining the value (147.27 fl) with 100% rubber seed meal in substitution groundnut cake in broiler diets [29]. Mean corpuscular volume is an imperative attribute which contributes to the cell size of red blood cells and it is also an essential factor in deciding the ability of birds' endure in delayed oxygen within the ecosystem [71]. It is envisaged that further processing of rubber seed through heating or fermentation might take out such anti-nutritional factors and upgrade its nutritional quality [28, 31, 33].

Furthermore, over a decade, aquaculture had broadened its horizon, intensified, and diversified its production; aquaculture is one of the fastest growing animal protein sectors around the globe [72]. Aquaculture production in recent time gains enormous interest in the utilization of rubber seed meal as a possible alternative to conventional plant origin protein source known as soybean. Many studies have been conducted mostly in the Asian part of the world predominantly in Malaysia, Indonesia, China and India [31, 33, 64, 66, 73]. For instance, Suprayudi et al. [33] report positive response on the carp juvenile fed with processed rubber seed with the level of inclusion (50%) resulted to a comparable growth and feeding performance to other protein sources. Contrarily, according to the findings of Deng et al. [63] rubber seed meal above 30% to juvenile tilapia (*Oreochromis niloticus* x *O. aureus*) led to growth depression, which is also similar [74]. The decline in fish from haematological parameters increase abnormalities in the kidney and intestine which correlates with the level of hydrocyanic acid content in the diet. The reason behind the differences in their performances might be the levels of anti-nutritional factors, starch polysaccharide and physiological variation of species.

Similarly, an aquatic feeding trial was carried out by Sharma et al. [31] on *Labeo rohita* (Hamilton) for 60 days, based on the findings of the study, 20% level of inclusion performed the best without compromising the growth response and health status in term of haematological parameters. Lee and Wendy [64] equally concur with the findings that ensue from the previous study on the level of inclusion and growth response. Furthermore, Fawole et al. [73] adopt the isolation of rubber seed to enhance the nutritional quality and increase its utilisation for sustainable aquafeed production. Isolation of protein is a technique that involves the seclusion of unadulterated protein fractions from other non-proteinaceous components present in the edible ingredients including anti-nutritional factors. Devappa and Swamylingappa [75]; Saetae and Suntornsuk [76] thus increases the palatability, metabolism and nutrient utilisation.

Interest in alternative feed has broadened to all classes of livestock which the large animals are no exception. Chanjula et al. [17], conducts feed trials with six male crossbred (Thai Native × Anglo Nubian) goats for 21 days. In the study, usage above 20% of rubber seed meal led to lower daily DMI, digestibility and nitrogen intake was also affected. The appropriate level of incorporation of rubber seed meal is 20% for optimal performance which corresponds with the earlier scholars [19, 31, 70]. A microscopic view of this study shows that the rubber seed meal exhibits considerable quality compared to conventional feed protein source which is scarce, expensive, genetically modified, and competition for its usage by domestic and industrial purposes.

4.2. Existing Development of Rubber Seed as Feed

Numerous researches have been conducted to enhance the usage of rubber seed meal on all classes of livestock, but no commercialised diets or ration have been developed from rubber seed. The usage of rubber seed meal is found to be more prominent on aquaculture with positive outcomes. Monogastric and ruminants have not fully explored the usage of rubber seed based diet for production.

4.3. Future Development of Rubber Seed as Edible Feed

Rubber seed had been adopted for several research purposes in the recent time due it promising crude protein contents as it is widely available and underutilized in most Southeast Asia and West African nations. One of the major constraint in the development of rubber seed as an edible feed ingredient is the inadequate data on production of rubber seed per ha which could give the insight to feed industry of viability of the rubber seed as an alternative to conventional feed. Globally, nutritionists have strengthened search to non-conventional feed due to the competition between man and livestock needs. Moreover, rubber seed meal contains some anti-nutritional factors that inhibit the availability of nutrients for livestock utilization which could be addressed with appropriate process techniques harmonized nutritionists in the nearest future.

5. Conclusion

Rubber seed is neglected biomass but has promising nutritive value as feed and food resources in most production nations. With an appreciate value of 20 to 30% crude protein contents and optimal amino acid composition that support growth and development. Therefore, if rubber seed meal could be incorporated in the livestock diet, it would reduce cost production. The main limitation in rubber seed meal is the presence of cyanogens compound but this drawback can be overcome by boiling and storage time. In conclusion, the rubber plantain and its by-products have numerous socio-economic benefits to the society.

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