



The Advances of Plant Product Meat Alternatives as a Healthier and Environmentally Friendly Option for Animal Meat Protein Consumption

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Authors' contributions

This work was carried out in collaboration among all authors. Authors DJF, FCN and ERA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TMA, BLT, TEF and NTN managed the analyses of the study. Authors DJF, NPN, EAES, BLT, NBN, BLF, KCN ' managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

High protein from meat consumption has been associated recently to environmental depletion and health related issues despite the important contribution of meat and meat products in diet and growth development. This has motivated debates on a drastic shift from excessive meat consumption amongst stake holders, academics, animal rights activists and environmentalist as informed consumers are pushing food scientist for a more sustainable alternative protein source. Plant proteins are considered a suitable alternative protein. However, the nutritional, functional potential and the form of presentation have shown some technological difficulties which indicates that direct transformation of plant proteins to meat products is less feasible. Though meat alternative research is promising in developed countries, there are technological breakthroughs that have permitted to replace in part or fully certain sensory attributes of meat inspired by the technology behind the ancient east Asian traditionally structured products like tofu, seitan and tempeh. However, despite the global increase in meat consumption associated with high standard of living, the search for the meat protein alternative from plant products have been limited to the conventional sources of soybeans, beans, lentils, vegetables and pulses. Future research could be diversified and orientated towards improving the existing African foods produced endogenously from wild orchid tubers widely consumed in low middle income countries in the form of cakes, meat substitutes, fake meat, mock meat and/or meat replacements. The successful production of a convenient and acceptable plant-based meat replacement will go a long way to reduce or eliminate excessive meat consumption. This review is geared towards a wider data search concerning the advances in meat alternative research and particularly to illustrate on some neglected African endogenously processed products consumed as meat alternatives that needs further research on the wild tubers sources as ingredients for potential convenient and acceptable meat alternatives or extender.

Keywords: Meat alternatives; non-animal protein; healthy and environmentally friendly; wild orchid tubers; low middle income countries.

1. INTRODUCTION

Meat has been an important diet component in many food cultures since prehistoric era, and principal meals are often composed around such protein supply [1]. Nutritionally, meat is one of the main sources of animal protein in foods [2] The red meat represents a nutrient rich protein food that is stored for complete protein with all essential amino acids, highly bioavailable iron, zinc, selenium, and B vitamins, especially vitamin B-12 in the diet [3]. Although, the prevailing increased in the world's population and potential rise in disposable incomes due to development and modernization might lead to an increase in global meat consumption [4,5] of about 72% by 2030 [6,7], the perceived health, social and environmental [7] impact linked to high levels of meat consumption is of great concern. An important global debate is ongoing among policy makers, practitioners and academics [5,8] to recommend for the global reduction in meat consumption. The sensitization for a healthy and environmentally sustainable food consumption has directed many towards a plant protein-based meat alternative and this requires that new

products fulfill consumer demands for acceptance by contributing significantly to salvage the prevailing environmental challenges [9,10]. In most cases, supporting a healthy diet is critical for both individual well-being and containment of treatment cost [11]. A radical change is therefore necessary to address the short comings of the present food system within the present globalization [12,13] required as the health and environmental target will not be achieved by the current trend of the food system [14]. Though changes in dietary habits (patterns and choices) might be a plausible solution to reduce excessive consumption of meat and animal protein products [9,15], partial and/ or total substitution of meat by plant-based products is regarded as an emerging strategy to achieve the goal [16,17]. The development of protein from sources other than conventional plants and livestock has therefore been the focus of food scientist in the last decades [18].

However, some "food futurologists" anticipate new products in order to create new food cultures from the known sensory experience [19] while others, in addition to products that replace

meat will wish to orientate the research towards products that partially substitute or “extend” meat [20]. Though, insects might have received considerable attention for the diverse and simple application [21], fungi-derived proteins (mycoprotein) products from *Fusarium venenatum* [22] are amongst the most commercially successful novel products to date [23].

Plant proteins are therefore a versatile source for animal protein and meat alternatives are considered one of the most suitable methods to introduce plant proteins in order to propose a wider range of proteins for human foods [24]. Though traditionally structured products like the east Asian tofu, seitan and tempeh [25,26] and the African Chikanda, Kinaka [27,28], *Napsie* [29] and *Nyam ngub* [30,31] had been in existence for decades; meat analogues research is a budding area in Europe and the Americas dating back to the early 1960s [32]. In fact, many of the modern technologies that are used to manufacture meat analogues today were first patented in 1947 and 1954 [33]. As a result, the development and production of meat alternatives especially plant-based products is hampered by the limited understanding of meat analogues and scarcity of individuals working in the domain [34]. However, the increasing health concerns and the related environmental issues associated with excessive meat consumption is driving the increase in demand for a plant-based meat alternative [35,36]. The aim of this review, besides presenting the current status of research on meat alternative (particularly plant-based meat products) and presenting the benefits of replacing/ substituting meat with plant-based alternatives, is to expose some African traditionally structured products that have been endogenously designed and consumed as meat-like products especially by the underprivileged.

2. IMPLICATION OF MEAT PRODUCTION AND CONSUMPTION

Although the importance of meat protein in human diet in the course of evolution cannot be underestimated [37,38], meat protein production is considered to impose a burden on the environment [39] and linked to a variety of chronic diseases [40]. Environmentally, animal meat production is a principal driver of environmental change and natural resource depletion [41]. The livestock sector accounts for an estimated 40% of global arable land, 36% of crop calories produced, and 29% of agricultural

freshwater use [42]. Following emissions, animals production is linked to 14.5 -24% of all human greenhouse gas (GHG) emissions [43] of all CO₂ emissions which is the main contributor of global warming [44]. United Nations (UN) report in 2006 indicated that emissions from cattle rearing were higher than all of traffic emissions combined [14]. Food and Agricultural Organization (FAO) reports have also been critical about the ecological impact of high levels of meat consumption [45].

Studies in recent decades correlates consumption of red or processed meats to a variety of non-communicable and chronic diseases such as multiple types of cancer, various forms of cardiovascular disease, kidney disease, type 2 diabetes, obesity, and total mortality [40]. The UN on its part has recognized the inappropriate use of antimicrobials in animals as a leading cause of the rising occurrence of antimicrobial resistance [46] which is critically an important global public health threat [47]. More information from the International Agency for Research on Cancer (IARC), WHO's cancer agency, has classified the consumption of red meat (particularly processed meat) as carcinogenic to humans [48] with a long term negative health implications like predisposing to colon cancer and the use of hormones in meat production correlated to high risk of breast cancer in women [49,50]. Apart from environmental and health sustainability, ethical consideration with respect to animal welfare are factors that meat consumption should be reduced [49-51].

Meat consumption (Table 1) has been predicted to lead to 2.4 million deaths and a total healthcare costs of 285 billion dollars globally by 2030 [52], and the per capita consumption of meat protein is expected to fall significantly. Consideration is that an average citizen is expected to practice a 75% decrease while citizens of the western hemisphere is expected to require about 90% drop for global climate targets to be attained [12].

3. BENEFITS OF A PLANT-BASED MEAT ALTERNATIVES

The benefits of cutting down on excessive meat consumption by considering a plant-based protein source despite the absence of a proper resemblance to meat is enormous and diverse (Table 2).

Table 1. Food consumption of meat

	1964/66	1974/76	1984/86	1994/96	1997/99	2015	2030
	kg per capita, carcass weight equivalent						
World	24.2	27.4	30.7	34.6	36.4	41.3	45.3
Developing countries	10.2	11.4	15.5	22.7	25.5	31.6	36.7
excl. China	11.0	12.1	14.5	17.5	18.2	22.7	28.0
excl. China and Brazil	10.1	11.0	13.1	14.9	15.5	19.8	25.1
Sub-Saharan Africa	9.9	9.6	10.2	9.3	9.4	10.9	13.4
Near East/North Africa	11.9	13.8	20.4	19.7	21.2	28.6	35.0
Latin America and the Caribbean	31.7	35.6	39.7	50.1	53.8	65.3	76.6
excl. Brazil	34.1	37.5	39.6	42.4	45.4	56.4	67.7
South Asia	3.9	3.9	4.4	5.4	5.3	7.6	11.7
East Asia	8.7	10.0	16.9	31.7	37.7	50.0	58.5
excl. China	9.4	10.9	14.7	21.9	22.7	31.0	40.9
Industrial countries	61.5	73.5	80.7	86.2	88.2	95.7	100.1
Transition countries	42.5	60.0	65.8	50.5	46.2	53.8	60.7
Memo item							
World excl. China	28.5	32.6	34.3	34.1	34.2	36.9	40.3
World excl. China and transition countries	26.5	29.0	30.6	32.4	33.0	35.6	39.1

Source: United Nations Food and Agriculture Organization, 2003. World agriculture: toward 2015/2030, an FAO perspective." [accessed April 15, 2018]

3.1 Land Use

Animal agriculture takes up 77% of all agricultural land while supplying only 17% of world's food [53]. As a result, there is always a renewed need for agricultural expansion and this represent the largest driver of ecosystem damage on land [54].

3.2 Greenhouse Gas Emission

Generally, animal agriculture is the main contributor to climate change than exhaust emissions from the entire transportation sector [55]. The principal ingredients for plant-based meats have very low greenhouse gas emissions [56] and advance processing accounts for only 13%–26% of plant-based meat's climate

impact [57,58]. The cropland no longer necessary for animal feed could be used to manage climate change through reforestation, soil conservation, or renewable energy production [59].

3.3 Water Expense

Out of the 1/3 of global agriculture water guzzled by animal production 99.8% is used in the cultivation of feed crops and draining aquifers [60]. Though processing accounts for 14–45% of plant-based meat total water use [57,58], conventional meat production water use is greater than that of any plant-based meat evaluated so far since plant-based meat products require mostly the crops that end up in the final product.

Table 2. Comparative evaluation of the benefits of plant-based meat-like products to conventional meat protein products on the environment

Plant-based meat-like products	Conventional meat products	Reduction of environmental impacts (% per kg of meat analogue)			
		Land use	Greenhouse gas emissions	Water use	Aquatic eutrophication potential
		m ² -y/kg	kg-CO ₂ -eq/kg	L/kg	g-PO ₄ ³⁻ -eq/kg
Impossible Burger 2.0 ⁷	Beef burger*	96%	89%	87%	91%
Beyond Burger ⁸	Beef burger**	—	89%	99%	—
Grillers Original Burger ⁹	Beef burger*	93%	85%	95%	77%
Spicy Black Bean Burger ⁹	Beef burger*	97%	89%	96%	76%
Roasted Garlic & Quinoa Burger ⁹	Beef burger*	93%	88%	98%	73%
Grillers Crumbles ⁹	Ground beef**	99%	90%	96%	—
Original Sausage Patties ⁹	Pork sausage patties*	47%	30%	81%	51%
Original Chik Patties ⁹	Breaded chicken patties*	84%	36%	72%	75%

This table represents the results of all English-language comparative life cycle assessments of plant-based meat conducted as of May 1, 2019.

^{7,8,9} *Because each study differs slightly in its methodology, the results from different studies cannot be precisely compared. *Sold frozen.*

***Sold fresh. Impact reductions are calculated as follows: (impact of conventional meat - impact of plant-based meat) ÷ (impact of conventional meat)*

3.4 Aquatic Nutrition Pollution

Animal agriculture is among the principal sources of eutrophication which is a leading threat to global water quality [61]. Eutrophication occurs when nitrogen and phosphorus run off into waterways, stimulating growth of algal blooms that suffocate aquatic life and therefore doubly harmful [61]. thanks to pollution from the fertilizer used on feed crops and the manure animals produce [62].

3.5 Use of Antibiotics

In USA, over 70 % of approved antibiotics are used in animal agriculture [63]. As healthy Animals are customarily fed low doses of antibiotics which are used in human medicine to speed growth and prevent disease, bacteria tend to adapt and become resistant [64]. Hospitals therefore face difficulties to defend against these adapted and resistant microbes [65]. If the antibiotic is left unchecked, predictions indicate that by 2050 drug-resistant microbes could potentially kill 10 million people annually and cause a cumulative \$100 trillion in economic damage [63].

4. MEAT ALTERNATIVES

Myriads of definitions or descriptions have been proposed for products used to replace and/ or substitute meat based on the three different strategies introduce to reduce excessive meat consumption. Malav et al. [66] naming the product meat analogues, defined it as food products that are designed to have sensory properties that are similar to meat but are made from plant proteins. Meat analogues are also considered as food products that simulate the aesthetic, organoleptic, and chemical characteristics of traditional meat products [67,68]. Taylor et al. [69] named the product as hybrid meat, and defined meat analogues as meat products in which a portion of the meat is substituted by another food ingredient. Elzerman et al. [70] laid emphasis on the word alternative to defined the products as plant-based processed products with the focus of imitating the taste of meat and also being a source of protein. Shurtleff and Aoyagi [33] reported that, meat alternatives should indicate the meat to which the product is an alternative and that the label must indicate clearly that the product is meatless. The researchers proceed by underlining that meat alternative and meat substitutes could be used interchangeably and defined it as a meatless food that has mainly the

same taste, appearance, and texture of a related food produce from meat, poultry, fish or shellfish. Joshi and Kuma, [71] indicated that meat analogue are also called meat substitute, mock meat, *faux meat*, or imitation meat developed to approximates the aesthetic qualities (primarily texture, flavour, and appearance) and chemical characteristics of specific types of meat.

Generally, meat analogue or substitute is a food made from non-meats ingredients generally of plant sources, sometimes without dairy products and may be available in different forms and textures.

5. MEAT ALTERNATIVE PRODUCTION TECHNIQUES

In principle, the conventional development of meat alternatives is made of two main steps: mixture preparation and chunk formation [72]. These techniques follow either a bottom-up or a top-down procedure to produce a fibrous morphology depending on the starting ingredients (Table 3).

5.1 Bottom-up Techniques

5.1.1 Culturing

This involves *in vitro* culturing of animal muscle cells by tissue-engineering techniques after which the muscles cells are transformed into meat [74,75]. The culturing of muscle fibres starts with the harvesting of myoblast cells from the skeletal muscle of the animal of interest and the cells replicated by a standard cell culture methodology using serum-supplemented medium with all the necessary nutrients, including amino acids, lipids, vitamins and salts, for cells to grow. The cells are placed onto a scaffold with anchor points for connection and alignment, yielding a multicellular tissue. The muscle fibres of about 2–3 cm long and less than 1 mm thick mature in approximately 3 weeks and can be harvested. Muscle fibres have actually been used to make a single hamburger as a proof of concept [76].

5.1.2 Mycoprotein

Although the process is relatively intensive in resources (energy usage and ingredient production), the filamentous fungus *Fusarium venenatum* has been used since the mid-1980s as a basis for the production of meat analogues

Table 3. List of traditional meat alternative ingredients, purpose and level of use in production

Ingredient	Purpose	Usage level (%)
Water	Ingredient distribution Emulsification, juiciness, cost	50 to 80
Textured vegetable proteins: textured soy flour, textured soy concentrate, textured wheat gluten, textured protein combinations such as soy and wheat	Water binding, Texture/mouthfeel Appearance; protein fortification/nutrition Source of insoluble fiber	10 -25
Nontextured proteins: isolated soy proteins, functional soy concentrate, wheat gluten, egg whites, whey proteins	Water binding, emulsification Texture/mouthfeel Protein fortification/nutrition	4 to 20
Flavors/spices	Flavor: savory, meaty, roasted, fatty, serum Flavor enhancement (for example, salt) Mask cereal notes	3 to 10
Fat/oil	Flavor, texture/mouthfeel Succulence, Maillard reaction/browning	0 to 15
Binding agents: wheat gluten, egg whites, gums and hydrocolloids, enzymes, starches	Texture/"bite," water binding, may contribute to fiber content, can determine production processing conditions	1 to 5
Coloring agents: caramel colors, malt extracts, beet powder, FD&C colors	Appearance/eye appeal Natural or artificial	0 to 0.5

Source: [73]

that are marketed under the brand name Quorn [77]. Bioreactors under monitored and strictly controlled critical conditions like temperature and pH are used in a continuous fermentation process to produce the fungus. After the fermentation, RNA is broken down into monomers by heat treatment to facilitate escape from the cells. The residual biomass undergoes heating and centrifugation to produce a paste-like product with 20 wt.% solids [78] after which filamentous fungus is disordered in preparation for further process steps, such as forming, steaming, chilling, and texturizing, are required to obtain fibrous products. Minced-type products, such as chunks, sausages, and burgers, are commercially available from this material [79].

5.1.3 Wet spinning

Wet spinning is mostly used for the creation of individual fibres. It is amongst the standard

techniques used to produce membranes for industrial separations [80]. The techniques involve extruding a protein solution through a spinneret and subsequently immersing into a bath containing a non-solvent for the protein. The exchange between the solvents precipitates and solidifies the extruded protein phase to form a stretched filament of about 20 μm thicknesses [81]. Studies have indicated the use of plant-based materials such as soy, pea and faba bean to produce food-grade fiber [81].

5.1.4 Electrospinning

This involves introducing a biopolymer solution through a spinneret with an electric potential relative to the ground electrode. The charges that accumulate at the surface of the droplets emerging from the spinneret causes surface instabilities that ultimately grows into very thin fibres (≈ 100 nm) which are attracted to the ground electrode [82]. Since the proteins are

usually required to be highly soluble and behaving like a random coil instead of globulins, plant proteins in most cases do not meet the requirements since plant proteins are globular in the native state but will form insoluble aggregates during denaturation. However, food-grade electrospinning is generally presented for uses in which nanofibers are employed as carriers or delivery systems for bioactive metabolites, such as polyphenols and probiotics [83], but electrospinning can also be used to produce fibres for the application of meat analogues [84].

5.2 Top-down Techniques

5.2.1 Extrusion

Extrusion is the most widely used commercial technique to transform plant-based materials into fibrous products [41,85]. The two classes of structuring that exist with extrusion are low-moisture and high moisture [86].

5.2.2 Mixing of proteins and hydrocolloids

Fibrous products can be obtained by mixing protein with hydrocolloids that precipitate with multivalent cations [87]. After mixing, the fibrous products are washed and the excess water is removed by pressing, yielding dry matter contents between 40 and 60 wt.%. Despite the initial ordering in the shear direction, the subsequent steps destroy this large range ordering, limiting the use to minced meat products, such as burgers and schnitzels.

5.2.3 Shear cell technology

Shear cell technology is a technology based on well-defined shear flow deformation introduced a decade ago to produce fibrous products [88]. Shearing devices inspired on the design of rheometers [89] called shear cells are developed in which intensive shear can be applied in a cone-in-cone geometry [90,91]. The final structure obtained with this technique depends on the ingredients and on the processing conditions. Fibrous products can be obtained with calcium caseinate and several plant protein blends, such as soy protein concentrate, soy protein isolate (SPI) – wheat gluten (WG), and SPI - pectin [92,93]. The structures prepared with calcium caseinate showed anisotropy on a nanoscale, while for the plant-based material, anisotropy was reported up to the micrometre-scale. The technology was successful up to pilot scale [94].

6. MAJOR CONSTRAINTS AND FUTURE CHALLENGES

The organoleptic quality especially texture and taste are the current challenges in the development of meat alternatives [32]. Apart from the doubted success to create plant-based meat alternatives due to the strong taxonomical factors adhering to meat as animal product [95], the creation of a novel protein food with the sensory attributes of meat is still a potential barrier [96]. A number of allergenic food proteins like dietary purines have been characterized in legume crops including soybeans, lentils, common beans, mung beans, chickpeas and peas [97,98]. New base materials such as isolated and concentrated proteins with low dietary purines content [99] are introduced in an attempt to manage the concentration as dietary purines are not recommended for hyperuricemia. Although, saponins and isoflavones were previously considered as undesirable substances for the anti-nutritional activities, the phytochemicals are presently considered useful but in a low concentration ranges for the anti-carcinogenic activities [100]. Also, products prepared from wheat, rye, and barley are not suitable for individuals suffering from celiac disease (CD) since the damaged absorptive epithelium of the small intestine is intolerant to gluten proteins [32]. These constraints have contributed in the limited use of plant proteins for preparation of meat analogues.

7. CONSUMER'S ACCEPTANCE OF PLANT-BASED MEAT ALTERNATIVES

Generally, the target of meat alternatives by the manufacturer is to mimic the taste and consistency of the animal product and permit the transition to a more plant-based diet for new consumers [98]. Meat replacement is categorized following the corresponding meat category it is intended to mimic. Studies to investigate the consumer acceptance, appropriateness and sensory preferences of meat alternative products have been conducted [4,101,102]. It is reported that the taste and texture are particular sensory properties which are highly important for consumer's acceptance [103]. However, meal formats [103] and repeated exposure [104] will also contribute significantly towards the acceptability of meat substitutes and meat analogues [69]. Report by Hoek et al.[95], show that the resemblance of meat substitutes to meat in terms of texture, taste, appearance, and smell,

is important for consumers that have preference for meat. Studies have shown that many consumers indicated that it was necessary for the appearance of a meat substitute to be similar to meat products and that the method of preparing a meal with the substitutes be clearly defined [105]. Although consumers of another study emphasized on the taste and texture as important characteristics for acceptance of meat alternatives especially by meat eaters, it was observed that meat alternative does not implicitly need to possess exactly the same sensory attributes like meat to be accepted [106]. However, considering the feasibility of mimicking large chops of meat (such as steaks) with plant proteins, the introduction of 'meat substitute ingredients' and smaller meat substitutes that will be served as part of a dish (e.g. in a soup, a sauce, or as a topping on a pizza) are more acceptable [107,108]. All these considerations have directed the production of modern meat analogues which are praised for their ability to meet consumer expectations by providing meat-like appearance, texture, flavour, and mouth feel [68,101,109].

8. FACTORS AFFECTING THE SUCCESS OF MEAT ANALOGUES

Despite increasing consumer awareness of the environmental and animal welfare impacts of eating meat and the growing market for reduced-meat diets [110] the degree of consumer acceptance of meat analogues is uncertain [111].

8.1 Consumer Perceptions of Meat Analogues/Substitutes

The number of vegetarians and number of consumers who are reducing their meat consumption has been increasing in Europe over recent years [112,113]. Depending on the type of consumer, environmental, ethical and health reasons are responsible [114]. Studies on consumer's attitudes to meat analogues specifically, and plant-based diets generally, indicated that those already seeking to reduce their meat consumption are likely to purchase plant-based meat alternatives [115]. Familiarity, sensory attractiveness and the prevalence of food 'neophobia' certainly play a role in strengthening and dampening of public interest [104] (perceived) nutritional quality as shown in Table 4, of meat analogues and their safety compared with conventional meat is also likely to be an important factor in their uptake [102].

8.2 Supports among Environmental and Animal Welfare Groups

The civil society narratives are playing an important role in shaping public attitudes to meat analogues particularly to cultured meat [117]. The civil society are therefore contributing to sensitize the communities about the impacts of diets while environmental groups in particular are considered to be among the most helpful sources of public information [118]. The growing number of meat reduction campaigns such as 'Meat Free Monday' and 'Veganuary', among others, have also greatly influenced raising awareness of the benefits of eating less meat and promoting the consumption of more plant-based meat substitutes [119]. Most NGOs aim for moderate messaging that is accessible and appealing to mainstream audiences, in shaping their campaigns around meat consumption, and that is mainly to avoid creating a perception of the organization as radical in its mission [120].

8.3 Responses from Industry Incumbents

As observed in many sectors of the economy, powerful meat industry has an important role to play in either accelerating or dampening innovation depending on how profitable or risky is the innovation [121]. Others in the industry have taken a more aggressive and defensive approach to the fast increasing number of meat analogue companies: some industry well established in the US have lobbied for a clarification of legal definitions of meat and for more stringent regulation of meat-alternative labeling [122].

9. MEAT ALTERNATIVE DEVELOPMENT CONTRIBUTION IN AFRICAN COUNTRIES

Shurtleff and Aoyagi [33] indicated that the use of low cost meat analogues in less developed and developing countries has evolved due to the large numbers of relatively poor people and competition of food with consumer goods in the family budget. But, the contribution of African Traditional Food Technology or African Survival Strategies in the development of meat alternative indicates a lot of gaps in literature. However, African Traditional Food Technology and/ African Survival Strategies have a significant contribution towards the search for a healthier and environmentally friendly solution to excessive meat consumption through meat replacements.

Table 4. Nutritional composition of different food products – current as of September 2019

Product ^a	Energy value (kcal)	Protein (g)	Fat (g)	Saturated fat (g)	Cholesterol (mg)	Total carbohydrates (g)	Dietary fiber (g)	Na (mg)	Fe (mg)
Meat analogue products									
Beyond burger	221.24	17.70	15.93	5.31	0.00	2.65	1.77	345.13	3.72
Impossible burger	212.39	16.81	12.39	7.08	0.00	7.96	2.65	327.43	3.72
Morning Star farms grillers original burger	203.13	25.00	7.81	0.78	0.00	12.50	6.25	609.38	1.72
Boca all American veggie burger	140.85	18.31	5.63	1.41	7.04	8.45	5.63	492.96	2.39
Gardein meatless meat balls	166.67	15.56	7.78	0.56	0.00	10.00	3.33	355.56	8.33
Tofurky ham roast with glaze	203.70	20.37	5.56	0.46	0.00	18.52	0.93	592.59	1.76
Quorn brand chik'n nuggets	203.39	10.17	8.47	0.42	6.78	24.58	5.93	449.15	0.72
Traditional meat products									
Ground beef (93% lean, 7% fat), uncooked/raw	152.00	20.85	7.00	2.89	63.00	0.00	0.00	66.00	2.33
Ground beef (93% lean, 7% fat), cooked, pan-fried	182.00	25.56	8.01	3.29	84.00	0.00	0.00	72.00	2.82
McDonald's beef patty	266.67	23.33	20.00	8.33	83.33	0.00	0.00	400.00	3.33
Tyson fully cooked homestyle beef meatballs	300.00	15.56	16.47	5.88	47.06	5.88	1.18	352.94	2.12
Hormel cure 81 classic boneless ham	105.95	18.45	3.57	1.19	50.95	0.24	0.00	1038.10	0.83
Tyson fully cooked chicken nuggets	300.00	15.56	18.89	4.44	44.44	16.67	0.00	522.22	0.91

*aAll products are standardized to a 100 g serving.
Sources: [116]*

9.1 Chikanda

Some ethnic groups in Northeastern Zambia and the adjacent provinces in Tanzania, the Democratic Republic of Congo and Malawi are known for their high consumption of meat loaf-like dish called chikanda in times of famine or as a seasonal addition to their dietary staples [27,123,124]. This meat loaf-like dish is prepared by mixing ground orchid tubers with peanut flour, boiling and thickening the mixture in water and subsequent baking [125]. Although initially not very popular, chikanda or African polony [125,126,127] has over the past decades, gained popularity throughout the country as a nutritious snack generally sold as a snack along the streets, on markets, in supermarkets and on the menu of a la carte restaurants [128].

9.2 Chinaka (“Kinaka”)

Is a Malawian delicacy used as “Relish” prepared from *Satyrium cursonii* usually by cleaning, pounding the tubers in a mortar and cooking preferably with a locally produced “baking powder” called “Chidulo” though sodium bicarbonate can be used in the absence of chidulo. A “cake” mix is produced, poured into a container to cool and solidify after which it is cut into small pieces and cooked with groundnut sauce or tomato [125].

9.3 Napsie

Napsie or “ground meat” is a product of the Bagam people of Galim in the Western region of Cameroon prepared preferably with *Habenaria keayi* and *Habenaria zambesina* orchid species. The tubers and roots are mixed in the ratio of 1: 3 respectively, washed and ground separately on a stone to obtain pastes which are then mixed and a solution of lime stone or filtrate of wood ash (or from any other plant material) added. After proper mixing, it is packaged in flamed banana leaves and cooked in a closed Aluminium pot for about 45 mins to obtain a mucilaginous mass with a colour and consistency almost like that of cooked liver [29].

9.4 Nyam Ngub

Nyam Ngub as named by most fufu corn eaters or *chengni* from the Ngemba’s, achu eaters of the North West region of Cameroon is an endogenously processed food from terrestrial wild orchid tubers and consumed in the form of meat snack, relish, meat substitute and/ or meat

replacement [30, 31]. To produce *Nyam ngub*, the wild orchid tubers are washed, drained, crushed in a mortar after which water is added and mixed. Wood ash extract made from special woods and/ or plant stems is then added and homogenized after which the mix is packaged in flamed plantain leaves and steam cooked for about 40-60 mins. The gel-like cooked product is cooled and eaten directly or a the source eaten along with corn fufu, or other cereal related meals [30].

10. CONCLUSION

Even though Food technologists, nutritionist are faced with multiple technological challenges to transform plant proteins into a convenient and acceptable meat alternative attractable to meat lovers, there has been great advances in the structuring and formulation of plant proteins. Products analogues of meat or the total appearance of some meat parts have been achieved. However, the macro and micronutrient content of the plant based meat substitutes is still an issue of concern with meat protein source occupying a popular choice for consumers, though once the sensory attributes of texture, appearance and mouth feel are obtained, the meal format will imposed protein rich supplements to salvage the nutrient problem. Though the history of meat replacements is attributed to the East Asian countries principally, African traditional food science had developed plant-based products to serve as meat. At this moment when meat consumption and production is no more considered sustainable, research should be diversified to involve other sources of plant proteins like the orchid tubers rather than concentrating on the conventional sources such as soybeans, beans, pulses and lentils.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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