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DEVELOPMENT AND PROCESSING OF NOVEL FUNCTIONAL FOODS FROM BIOACTIVES OF PLANT ORIGIN: APPLICATIONS, RECENT TRENDS AND FUTURE PERSPECTIVES

Dubale Befikadu Chala*[a] and Shimelis Admassu Emire[b]

[a]Food Technology and Process Engineering Research Team, Oromia Agricultural Research Institute, Ethiopia.
[b]Department of Food Engineering, School of Chemical and Bioengineering, Addis Ababa Institute of Technology, Addis Ababa University, Addis Ababa, Ethiopia.

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***Corresponding Author**
Dubale Befikadu Chala
Food Technology and Process Engineering Research Team, Oromia Agricultural Research Institute, Ethiopia.

ABSTRACT

The focus on food's role has shifted from just suppressing hunger or providing the nutrients essential for normal cellular function to components to a variety of documented bioactive capabilities potentially boosting health and wellbeing, including illness prevention. The development of such functional food products is a multistage process that requires input from commercial, academic, and regulatory agencies, as well as a critical necessity to assure consumer acceptance. In response to consumer demand for foods containing health-promoting bioactive compounds, food companies are utilizing emerging processing technologies for health and wellness products, enhancing their efficacy, providing the greatest possible benefits to consumers, and ensuring the industry's long-term competitiveness. Novel study focusing on the utilization of bioactive-containing potential plant ingredients in food matrices, as well as their impact on physicochemical, functional, rheological, and sensory qualities, should be researched further.

KEYWORDS: Bioactives; processing; functional; foods; novel.

1. INTRODUCTION

Food is fundamentally the component required for various life sustaining functions such as energy generation, nutrients supply, supporting diverse metabolic activities in addition to body growth and maintenance whereas functional food is processed food comprising ingredients that assist specific body functions besides its nutritional content (Doyon and Labrecque, 2008; Kaur and Das, 2011). Functional food products are categorized as basic, enriched, fortified, altered, enhanced or processed (Aryee and Boye, 2015; Lane and Derbyshire, 2018). Basic/whole/unaltered products are foods containing increased content of nutrients naturally or components containing the natural level of the antioxidant β-carotene like in carrots while fortified products are those foods containing enhanced amount of existing nutrients via supplementation of extra amount of those nutrients like vitamin C in fruit juices (Boye, 2015; Gok and Ulu, 2019). Enriched or supplemented food products are those foods with containing newly added nutrients or components which is normally absent in a specific food like muffins with β-glucan or fruit juice enriched with calcium (Boye, 2015). Altered products are foods from which a harmful component has been reduced, removed, or replaced with another having useful effects like fibres does as fat releasers in ice cream or meat products (Aryee and Boye, 2015; Siró et al., 2008). Enhanced products are foods that have been enhanced to have more of a functional component via conventional breeding, genetic engineering or special livestock feeding like eggs with increased ω-3 through altered chicken feed and tomatoes with increased levels of lycopene. Processed foods are food products processed to have natural levels of their functional components like oat bran cereal possesing the natural level of β-glucan (Aryee and Boye, 2015; Boye, 2015). Reasons such as urbanization and its effect, transitional health, changing demography with aging population, loss of traditional food culture, food security and awareness of decline in personal health are among reasons brought by hectic lifestyles with poor choices of convenient foods and competitive market have driven functional foods development possessing a health promoting plant based functional bioactive ingredients (Kaur and Das, 2011; Dey and Sireswar, 2019; Gok and Ulu, 2019). Greater self-medication, increased levels of knowledge from health authorities, insufficient daily physical activity, and media coverage of nutrition, the relation between diet and health, and scientific advances in nutrition research are all elements that have an effect (German et al., 1999; Kaur and Das, 2011).

2. Major Health Benefits Of Bioactive Compounds Based Novel Foods

The inclusion of bioactive compounds in functional foods has been linked to a reduced incidence of coronary heart disease, diabetes, obesity, osteoporosis, cancer, and other chronic age-related degenerative diseases, according to epidemiological evidence (Olaiya et al., 2016). Consumers' plasma and tissues accumulate in response to their dietary intakes, inhibiting processes mediated by reactive oxygen species (Olaiya et al., 2016). Bioactive chemicals, whether in combination or alone, have therapeutic potential and have a variety of pharmacological and biological impacts on human health. Antiinflammatory, anticarcinogenic, antidiabetic, antifungal, antioxidants, antipyretic, antiapoptotic, hepato-protective, chemo-preventive, analgesic, hypo-lipidemic, CNS stimulant and cellular immunity stimulation among such health effects (Prakash et al., 2012; Olaiya et al., 2016; Madhumitha and Roopan, 2018). Bioactive-containing functional foods are becoming increasingly popular as an alternative to conventional medications and since they are less expensive, safer, and more readily available (Chatterjee et al., 2013; Olaiya et al., 2016).

3. Research And Development Advances In Novel Bioactives Enhanced Functional Foods

The most popular functional food products include dairy, bakery, soft drinks, confectionary, and infant foods (Menrad, 2003; Kaur and Das, 2011). The most known type of functional food products containing plant based ingredients are intended to lower elevated blood pressure, blood sugar, cholesterol, and osteoporosis have been launched into the market (Charalampopoulos et al., 2002; Kotilainen et al., 2006; Kaur and Das, 2011).

Cereal based

Cereals contain dietary insoluble fibers, a natural functional ingredient that acts as roughage, as well as water soluble fibers that selectively promote the growth of lactobacilli and bifido bacteria in the colon, acting as prebiotics and promoting several beneficial influence on physiology (Rodríguez et al., 2006; Vitaglione et al., 2008; Kaur and Das, 2011). Extracted plant ingredients have been added successfully into various novel products of food like chews, breakfast cereals, nutrition bars, baked products, pasta, beverages, yogurt, ice cream and dietary supplements. Besides extraction of specific components of food from cereals, processed whole cereal itself is high in minimally exploited bioactives that may function as antioxidant, hypocholesterolemic, anti-proliferative, stimulant of enzymes and hormones, carcinogen detoxifier, anti-inflammatory, antibacterial and antiviral, potential inhibitor of diverse actions and ligand to cell wall influencing the commencement and progression of a number of pathogenic processes (Kaur and Das, 2011). Cereals are in general appropriate substrates to the growth of human probiotic strains though it depends on factors like processing, composition and formation of substrate for the growth of probiotic strain. Resistant starch that is found in heated starch and starch containing cereal food products is also among functional fibers contributing to the fermentable carbohydrates for bacteria in colon, thus reduce the risk of bowel diseases (Charalampopoulos et al., 2002; Kaur and Das, 2011; Eksi et al., 2019). Investigation by Kushi et al. (1999) indicated an inverse relationship between whole grains and their dietary fibers versus cardiovascular disease and cancer in adults that raised in fasting plasmabetaine which tends to lower LDL cholesterol and fasting homocysteine by the consumption of wheat foods rich in its aleurone (Price et al., 2010; Kaur and Das, 2011).

Tea based

Tea mainly contains polyphenols, primarily catechins that covers 25 to 30 percent of the weight recovered from drying of fresh leaf of tea (Shi et al., 2005; Balentine et al., 1998; Kaur and Das, 2011; Sun-Waterhouse, 2011). Green tea polyphenols have anticarcinogenic, antioxidant, antibacterial, antiviral, antifungal, anticariogenic, thermogenic, antimutagenic, deodorizing, kidney protecting and blood lipid and blood glucose controlling characteristics (Kaur and Das, 2011). According to Zemel (2003) and Mermel (2004), consumption of green tea increases the basal metabolism and results loss of weight. Catechins in black tea form the aflavins and thearubigins following oxidation and offer its antimicrobial, antioxidant, anticancer and anti-inflammatory activities (Pasha, 2005; Kaur and Das, 2011).

Vegetables and fruits based

Vegetables and fruits posses health merits owing to quantity and kinds of phytochemicals they contain (Shahidi, 2009). Berries fruits have a variety of polyphenols, among which flavonoids including anthocyanins, cathecins and flavonols, phenolic acids such as hydroxycinnamic acids and tannins like ellagitannins and proanthoscyanidins are most important. Fruits of berry are used as colorant and as sweetener as well to aromate functional breakfast cereal products (Kaur and Das, 2011). The novel functional food ingredients associated with berry fruits are berry oils, berry seed oils, powders of berry, berry fiber powders and berry extracts. It enables protection against cardiovascular diseases, diabetes, cancer, premature ageing and gives healthier effect on brain function and eye sight (Yildiz and Eyduran, 2009; Kaur and Das, 2011). Through the ingestion of berry fruits with a particular mixture of fruit juice, the antioxidant capacity of the blood was significantly increased, and the action of lipid peroxydase was reduced (Yildiz and Eyduran, 2009; Kaur and Das, 2011). Red wine and red grapes are among fruits loaded with polyphenol resveratol reported to be anticancer, anti-inflammatory, cardio protective, antioxidant and lipid metabolism modulator and potent to control obesity and diabetes (Jang et al., 1997; Shahidi, 2009; Kaur and Das, 2011; Eksi et al., 2019). In-vitro, clinical and epidemiological investigations have

confirmed the health benefits of red wine against cardiovascular diseases and some cancer types (Kaur and Das, 2011). Lycopene, recognized to have preventive result on hypertension, oxidative stress, diabetes and atherosclerosis is a carotenoid antioxidant found in fruits and vegetable with red colors primarily in tomatoes and tomato based products (Day et al., 2009; Kaur and Das, 2011; Viuda-Martos et al., 2014; Eksi et al., 2019). A review from epidemiological results showed an inverse relation between consumption of tomato and tomato product versus risks for lung, stomach and prostate cancer and occurrence of coronary heart disease as well (Rao et al., 2003; Kaur and Das, 2011). Foods fortification using lycopene in dry fermented sausage by incorporating peels of dried tomato into meat, low quality edible oils enrichment by lycopene from tomato puree or peels to induce thermal stability, lycopene rich tomato pulp waste extract supercritical fluid encapsulation, barley-tomato pomace blends enriched extruded snacks, and lycopene-soy protein mixture, are among areas tried to be covered (Kong et al., 2010; Kaur and Das, 2011). Studies by Verhoeven et al. (1996) and Ovesen (1999) have shown that the vegetables consumption possessing high concentration of glucosinolates and β-carotene and risk of cancer have inverse relationships. Total carotene content was enzymatically extracted from pomace of carrot and incorporated to make functional drink (Stoll et al., 2003; Kaur and Das, 2011).

Herbs

Herbs are loaded with different functional food constituents which when applied in food in either whole or extracted form is valuable (Kaur and Das, 2011). Curcumin which is a yellow polyphenolic pigment has been found to show therapeutic potential in Parkinson's and Alzheimer's disease, epilepsy, cerebral injury, multiple sclerosis, cardiovascular disease, allergy, asthma, cancer, bronchitis, rheumatoid arthritis, colitis, renal ischemia, diabetes, obesity, psoriasis, depression and fatigue (Aggarwal and Harikumar, 2009; Kaur and Das, 2011). Clinical trials and epidemiological observations recommended that turmeric consumption may lessen the risk of some form of cancers and offers other preventive biological impacts in human (Goel et al., 2008; Kaur and Das, 2011; Eksi et al., 2019). Generally regarded as safe condition has been obtained for ingredient of curcumin antioxidant and can thus be incorporated to milk products, baked goods, jams and jellies, oils and fats, gelatins and soups, puddings, candy, snacks, and frozen dairy, seasonings and flavors and imitation non-alcoholic and dairy beverages, (Kaur and Das, 2011). Ginger is insulinotropic than being hypoglycemic possessing chemical components like gingerols and other flavonoids with antioxidant activity (Shakib and Gabrial, 2010; Kaur and Das, 2011). Antimicrobial and antioxidant compounds were extracted from rosemary using preparative supercritical fluid chromatography to be used as functional food ingredients (Ramírez et al., 2006; Kaur and Das, 2011). Other commonly used botanicals are ginkgo (*Ginkgobiloba*), St. John's wort (*Hypericum perforatum*), ginseng (*Panax ginseng*), kava (*Piper methysticum*), black cohosh (*Actaea racemosa*) and Echinacea (Kruger and Mann, 2003; Gruenwald, 2009). Antioxidant and antimicrobial activities of essential oil from Cymbopogon citrates have been reported to prevent unsaturated fatty acid oxidation (Sacchetti et al., 2005; Kaur and Das, 2011).

4. Major Plant Based Bioactive Ingredients For Functional Food Development

Bioactive compound is a compound found in animals, plants, or foods having effect on the body consuming it (Fernandes et al., 2019). Bioactive ingredients are thus ingredients upon incorporation in to foods, improves health. These ingredients can be found in natural bioactive substances such as dietary fibre, bioactive ingredient supplemented foods like antioxidants and probiotics, or fortified meals like in prebiotics (Sacchetti et al., 2005; Fernandes et al., 2019). Bioactive ingredients are a source food extracted compounds like fruits, vegetables, cereals and residues of food processing that maintain their features even after extraction. One point that needs to be known is that bioactive ingredients are different from food additives as certain food ingredients being used in the food industry to enhance or impart sensory features are only additives but not functional ingredients. The major bioactive ingredients consists of probiotics, prebiotics, peptides, amino acids, proteins, structured lipids, omega-3, minerals and phytochemicals, extracts of plant, fibres, carotenoids, vitamins, antioxidants and special carbohydrates, all of which can be obtained from different sources and are served in the form of beverages, personal care products, supplements and functional foods for consumers (Fernandes et al., 2019).

5. Novel Functional Foods Design And Development Principles

The development of foods having bioactive ingredients is gaining popularity as a result of various studies on getting these compounds, because the efficiency of nutraceutical and functional products in prevention of disease is dependent on the active ingredients' bioactivity, stability, and bioavailability (Vieira da Silva et al., 2016). Because of insufficient residence time in the gastric, low permeability and/or solubility in the intestine, and instability in the gastrointestinal tract or during food processing, a significant challenge is manifested as a small proportion of molecules only remains available after oral administration (Fernandes et al., 2019; Vieira da Silva et al., 2016). For the development of potential novel functional food products, the investigations are required with regard to the following points: bioactive compounds identification and quantification, the establishment of appropriate delivery systems and dosage to integrate bioactive compounds into foods, incorporated ingredient bioavailability and absorption the analysis, incorporated bioactive compounds safety testing, product storage stability

studies and research of potential interactions among active ingredients and other components of the food (Recharla et al., 2017; Fernandes et al., 2019).

Food processing method influences its functional components as some of the processing techniques raise the functional components concentration in the food, whereas others lowers it (Abuajah et al., 2015; Fernandes et al., 2019). It is thus essential to study the behaviour of bioactive compound during food processing, and bioavailability upon incorporation in to food matrix. Nonetheless, there are only few investigations on the bioactive compounds application as ingredients of food as most investigations are focused on getting these compounds, biodisponibility and evaluation of their properties. Biscuits were developed by incorporating fibre residue-rich grains to a considerable amount of bioactive compounds like carotenoids and polyphenols (Mildner-Szkudlarz et al., 2013; Fernandes et al., 2019).

According to sensory profile analysis, the authors concluded that biscuits at a level of up to 10% could be incorporated from white grape pomace to get sensorially acceptable products. Pomace of white grape at 10% enhancement results biscuits with 64.86 g of total dietary fiber per kg of dry matter and 30.51 mg phenolic compounds per 100 g dry matter. By-products of grape can thus be used as ingredients in new biscuit formulation as an alternative source for phenols and dietary fibre and thereby be a functional food (Fernandes et al., 2019). The extract of pomegranate peel was also incorporated in hazelnut paste by encapsulation to assess the extract's stabilizing efficiency against oxidative deterioration (Kaderides et al., 2015; Fernandes et al., 2019). The shelf life of hazelnut paste was found improved owing to efficiency of the encapsulated phenolic extract. Marsanasco et al. (2015) developed a functional food from incorporation of pasteurized chocolate milk, linolenic acid (omega-3) and essential fatty acids linoleic acid (omega-6). Liposomes indicated considerable stability with all of parameters and a protective effect over thermo labile fatty acids, with the remaining half of this vitamin been encapsulated. The addition of SPC had no effect on the acceptance of commercial milk. From 2011 to 2015, Lagos et al. (2015) have done a survey of patents on the bioactive chemicals application in various food businesses. Foods patents containing bioactive compounds are focused in the beverage industry, chocolate, and as a sweetener, according to the report (Fernandes et al., 2019).

6. Research Activities On Functional Food In Africa

In traditional African societies, food is clearly used both for satiation and for health promoting properties. Specific vegetables are prescribed for common colds and catarrh, abdominal pains, infections, to enhance female fertility, to promote male sexual virility, and various chronic conditions. Certain spices, resins, and bitter plant products with some physiological activities are deliberately added to many traditional recipes to enhance their health-promoting properties (Iwu, 2017). Some have argued that the increase in the incidence of many metabolic diseases, cancers, and chronic diseases could be due, at least in part, to the neglection of these protective indigenous remedies for processed imported food by the African elite. The ethnobotanical studies of African tribes have revealed the multidimensional aspects of plant use in which botanicals serve as constituents of both the herbal pharmacopeia and local diet (Iwu, 2017). In today's health-conscious populations, where people are worried about lifestyle induced health risks and the consequences of modernization, such as the effect of pesticide residue, genetic modification, concerns regarding high-tension power lines, cell phones, hormones and additives in food, chronic exposure to cancer-inducing radiation and vaccination programs the an ever-increasing demand for functional foods exists that could potentially protect individuals from such adverse agents (Devcich et al., 2007; Chen, 2011). Besides being rich in vitamins and minerals, plants contain bioactive compounds that act as medicines largely at cellular levels to repair damaged tissues, restore normal physiological functions, and enable the body fight diseases. Some of the compounds in plants are not necessarily produced by them but assimilated into their organs as constituents, making it possible for the same plant species grown under two different environments to contain a different mix of bio-chemicals (Iwu, 2017).

7. Testing Efficacy And Safety Of Functional Foods For Their Biological Effect

To prove that a novel functional food is useful to humans, it must be clinically studied and confirmed for safety. In vivo testing should be used to evaluate the health-claim formulations and functionality of potentially functional foods and ingredients (Granato et al., 2020). These processes are required in order to pick appropriate biomarkers for assessing the presence and degree of potential risks or health benefits connected to safety. Animal models and in vitro tests cannot prove cause-and-effect in humans, though they can provide evidence of functionality and are linked to the functional substance. The gold standard for clinical research to explore the health claims and safety of potential functional foods is a double-blind randomized controlled clinical trial with placebo controls using either a parallel or cross-over design (Granato et al., 2020; Weaver and Miller, 2017). Randomized controlled clinical trials avoid bias and confounding in research while allowing lawmakers to make causal inferences that allow medicinal and food labels health claims. The data should also be published in a peer-reviewed scientific journal so that the scientific community can evaluate it critically (Kamioka et al., 2019). The public and government should be informed of the valid and reliable outcomes of randomized controlled clinical trials, with a focus on public health protection. However, if a food product is well-known and well-studied, a systematic review or a meta-analysis of its functional substance(s) may be acceptable (Granato et

al., 2020). Relevant experts must achieve an evidence-based consensus after a thorough examination to establish whether or not the food/ingredient claim is justified (Jl, 2017; Lenssen et al., 2018). Randomized controlled clinical trials necessitate considerable human and financial resources and must incorporate work from diverse fields such as nutrition, food engineering, pharmacology, and the medical sector in order to produce precise and trustworthy results (Granato et al. 2017). In addition to these basic needs, Brown et al. (2018) identified additional technical challenges that the research team faces. These difficulties can be found in each of the three phases of a study: planning the trial, performing the trial, and lastly disseminating the data when the study is completed successfully, showing that conducting clinical trials is not a simple task (Granato et al., 2020). Those in the technological, nutritional, and medical fields must collaborate closely in order to provide results that can be used by scientists, legislators, and the in food industry research and development (Tanemura et al., 2018; Granato et al., 2020). Many epidemiologic approaches typically employed in the pharmaceutical and medical sectors must be incorporated into safety and efficacy evaluations of novel substances and prospective functional foods (Granato et al., 2020).

In an ideal world, the test would be a carefully planned randomized controlled clinical study that took into account essential practical and technical criteria to ensure the information gained was relevant and led to accurate and legitimate results (Brown et al., 2018; Granato et al., 2020). All food safety regulations demand that all foods are safe and without adverse effects. Any food, functional or traditional, cannot be guaranteed to be completely safe. Foods have to always be viewed as a potential source for hazardous components (Plaami et al., 2001). As a result, safety of food is a balanced assessment of benefits and the risks. However, unlike pharmaceuticals the risk and benefit concept cannot be applied in the same way. Because functional foods are so different, a checklist method to evaluating their safety is ineffective. a case-by-case approach must rather be used, considering the functional ingredient's composition, daily consumption, diet role, and intended target population. This is the population category for which functional foods are thought to be more beneficial than others (Plaami et al., 2001).

8. Animal Model Testing Of Functional Foods Efficacy And Toxicity

Efficacy testing, which can be done in vitro or in vivo, is required for the formation of legitimate functional food entities. Fundamental biological information about nutritional biochemical process interactions is provided by cell systems. However, using animal or human systems to quantify biological activity on a whole-body physiological basis is preferred (Jones and Jew, 2007). Animal systems provide for a great deal of control over diet, environment, and heredity, however there are many cases when animal models fail to appropriately reflect human physiological responses (Jones and Jew, 2007). Varying species have different lipid metabolisms, which should be taken into account when comparing the relevance of animal models to humans (Bergen and Mersmann, 2005; Jones and Jew, 2007). As a result, well conducted human studies are required rather than animal trials. Efficacy confirmation, particularly in a human system, provides a solid foundation for arguing that a product should be allowed to make a health claim. Clinical efficacy demonstration for a functional food product is an important step in the innovation process because it closes the gap of credibility for both the product claim and diet-disease idea (Jones and Jew, 2007).

9. Health Claim And Regulatory Aspects Of Functional Foods Having Bioactive Ingredients

The next step in the innovation cycle is to communicate to the general public the health messages created by active regulatory review and research of a specific food product. To transform peer-reviewed published findings demonstrating the safety and efficacy of a certain bioactive component inside a new food matrix or capsule into policy modifications consistent with product approval for functional food marketing, regulatory review is required (Jones and Jew, 2007). In order to secure a health claim, the supporting facts might be used directly or indirectly in promotional materials. In order for health claims to be accepted through the regulatory review process, functional food items must be carefully evaluated for efficacy and safety at each stage of the innovation cycle (Jones and Jew, 2007). Unfortunately, limited health claim regimes have created significant hurdles in communicating the food/health association to the general public in several jurisdictions. Regulatory procedures vary extensively around the world, with some countries, such as Japan, permitting over 500 functional foods while others, such as Canada, let a far smaller number of health claims (Jones and Jew, 2007).

10. Regulation Of Health Food

Traditional medicine entails the extraction, expression, distillation, fractionation, purification, concentration, and fermentation of a whole, fragmented, or cut plants, algae, lichens, fungus, and botanical preparations from these materials (Bahorun et al., 2008). Nevertheless, the manufacturing process, purifying and drying procedures used, solvents/additives used, and storage conditions all play a part in the presence of substantial amounts of pollutants, pesticides, microbes, heavy metals, toxic compounds, or solvent residues in the samples. As a result, defining and implementing thorough, standardized manufacturing stages/procedures, a quality control and quality assurance methodology is critical (Bahorun et al., 2008).

In 1984, The Dietary Supplement Health and Education Act (DSHEA) in the United States gave consumers easy access to high-quality, safe, and effective dietary supplements (Bahorun et al., 2008). This act for

regulating supplement products has been adopted and changed in a number of different countries. nutraceuticals sale, manufacture, packaging, labeling, importation, distribution, and storage were all regulated under Natural Health Products legislation in Canada, which were enacted in 2004 (Nestmann et al., 2006; Bahorun et al., 2008).

Similar nutraceutical regulation is carefully enforced throughout the European Union, while there appears to be some inconsistency in the legal status of specific botanicals among European countries. Numerous functional foods or food-derived compounds, for example, are sold as foods in the United States, but they are classified herbal medicines in other European nations and are subject to complete and streamlined registration requirements (Gulati and Ottaway, 2006; Bahorun et al., 2008). Because there is now no standard regulatory framework in place to analyze these natural health products, similar examples can be found all over Africa. Food and medicinal plants possess a pool of bioactive chemicals with potential therapeutic benefits on human health that have yet to be discovered (Bahorun et al., 2008). Consumers, farmers, and the health and food production industries are eventually concerned about how the respective government's regulation addresses the benefits and risks of plant origin active components, and how this will influence the products commercialization and their ultimate success (Bahorun et al., 2008).

11. The Neglected And Underutilized Plant Origin Bioactive Compounds In Ethiopia And Africa

Climate change is posing enormous problems to staple foods, which will continue in the future. To attain food security, crop diversification, including neglected crops, is crucial. Underutilized, neglected, or orphan crops are plant species that have lost their value over the last 500 years due to societal, agronomic, or ecological factors (Hernández Bermejo et al., 1994). Some neglected crops' initial purpose in terms of their prospective uses has been marginalized through time, while others have been practically forgotten. These crops are plant species that have played an important part in indigenous peoples' and communities' agriculture and food supply (Hernández Bermejo et al., 1994). Since neglected crops are nutrient-dense and contain health-promoting chemicals that help avoid malnutrition and some chronic diseases and the ability to thrive in marginal or stressful environments, they offer a lot of potential for boosting nutrition in local populations (Hernández Bermejo et al., 1994; Baldermann et al., 2016). Bioactive chemicals derived from plants perform unique biological roles and influence many physiological systems to improve human health (Niaz et al., 2020; Keyata et al., 2021; Hernandez-Ledesma and Herrero, 2013). The use of these compounds to lessen the incidence of prevalent non-communicable diseases in adults has grown widespread. Many phytochemicals, as well as proteins, lipids, carbohydrates, vitamins, and minerals, are found in plant-based diets (Narzary et al., 2017; Keyata et al., 2021). Plant phytochemicals are powerful antioxidants that protect the body from reactive oxygen species. They also provide a range of health benefits (Narzary et al., 2017; Keyata et al., 2021). Phytochemicals are found in plant food, and a single plant might include over a thousand different phytochemicals (Keyata et al., 2021). Varying underutilized plants have different levels of phytochemicals. Underutilized plants in many countries are regarded to represent potential sources of various types of health-promoting bioactive compounds. Okra (*Abelmoschus esculents*), girgir (*Eruca sativa L.*), figl (*Raphanus sativus L.*), and moringa (*Moringa oliferain*) are among the indigenous underutilized plants in southern Ethiopia (Gemede et al., 2018). (Debebe and Eyobel, 2017; Keyata et al., 2021). Karkade (*Hibiscus sabdariffa L.*) (Olika Keyata et al., 2020; Keyata et al., 2021) and anchote (*Coccinia abyssinica*) have been mentioned in the western and south western parts of Ethiopia, respectively (Parmar et al., 2017; Keyata et al., 2021). In Benshangul Gumuz regional state, which is close to the Sudanese border, dried calyx of Karkade is extensively used to prepare hot and cold beverages (Keyata et al., 2021). Figl roots and leaves are used in salads or cooked vegetables, whereas Girgir leaves are consumed as a vegetable. The calyces of Karkade, according to research reports from various countries, have significant levels of total flavonoid, total phenolic, and total anthocyanins, all of which have strong antioxidant effects (Shruthi et al., 2017; Keyata et al., 2021). Mazzucotelli et al. (2018) and Sarikurkcu et al. (2017) reported that figl and Girgir leaves were good sources of phenolic, flavonoids, and antioxidants, respectively (Keyata et al., 2021). In Tigray, Amhara, and the Southern Nations, Nationalities, and Peoples (SNNP) region, anchote (*C. abyssinica*) is cultivated sporadically (Teshome et al., 2020). The crop has been produced for its nutritious tender leaves and tuberous roots since ancient times (Teshome et al., 2020). Its succulent leaf component, which is eaten as a cooked vegetable, contains a high amount of bioactive compounds, primarily polyphenols. *Tacca leontopetaloides* tubers are a staple meal in Mozambique, and a study found that most rural residents rely on them to supplement essential deficits such as minerals, lipids, proteins, carbohydrates and vitamins (Ukpabi et al., 2009; Uarrota et al., 2019). Cassava is a staple diet for 800 million people in South America, the Caribbean, Africa, and Asia, according to estimates (Latif and Müller, 2015). It is mostly grown for its amylaceous roots, but the leaves are consumed in at least 60% of Sub-Saharan African countries, providing a valuable source of proteins, vitamins, and minerals (Uarrota et al., 2019).

12. Functional Food Market Potential In Africa

New scientific and technical methods to food processing, as well as the introduction of innovative foods, are among the most recent food industry developments, with functional foods playing a key role, as indicated by rising health-care expenses and an increasing need for

improved quality of life (Kotilainen et al., 2006). Market globalization has raised demand for innovative functional food items, notably in the food industry (Kotilainen et al., 2006; Annunziata and Vecchio, 2011). Traditional knowledge of the functional, preventative, and even therapeutic properties of particular foods has long been prized in Africa, Southeast Asia, and Latin America. The demand for innovative functional food products has increased as market globalization has increased, particularly in the food sector. Traditional wisdom has historically been valued in Africa, Southeast Asia, and Latin America, with extensive knowledge of the functional, preventative, and even curative aspects of various foods (Kotilainen et al., 2006). However, high pricing of functional food products in developing countries, such as Africa, tend to exclude low-income people who could benefit the most from the products. In more established markets, the functional food sector has commercial export prospects in functional ingredients, value-added raw materials, and even consumer products (Kotilainen et al., 2006). Underdeveloped infrastructure, an unorganized and fragmented retail network, a lack of research facilities and little collaboration between academic research and the industry, a focus on bulk commodities with low processing levels, high ingredient costs, and high costs in meeting food safety and quality regulations are all suggested as key concerns that require attention and empowerment. Governments' responses to these issues, as well as international organizations' and the private sector's reactions and facilitation of the process, will determine the future of functional food product markets (Kotilainen et al., 2006). Unlike the pharmaceutical industry, Africa has made a significant contribution to the world's major food crops, with numerous key species such as coffee, sorghum, oil palm, cow pea, millets, and cocoa (Iwu, 2017). Many African crops are highly valued as commodities in international trade (Van Wyk, 2011). These figures show that the development of African indigenous functional foods as commercial products for domestic and international markets has significant potential (Iwu, 2017).

13. CONCLUSION AND RECOMMENDATIONS

13.1 Conclusion

Emerging technologies offer a quick, efficient, and dependable way to improve food quality while also allowing for the development of unique functional items. It's worth noting that the majority of these new technologies are currently undergoing extensive scientific investigation on a smaller scale, despite the fact that they've been fully applied in a few cases. Following an increase in consumer demand for health-promoting products, current practices and trends in food processing have resulted in changes in the way bioactive plant ingredients are included into foods for market. Epidemiological and clinical research have demonstrated the beneficial or neutral effects of consuming various types of bioactive compound-containing foods on health and wellness, as well as a risk factors reduction for specific diseases. Functional foods manufactured from bioactive ingredient sources of plant origin have generated awareness and an overall favourable attitude among health-conscious customers. Their favourable effects can be summarized as a risk reduction for cardiovascular disease, cancer, weight loss or management, osteoporosis, enhanced memory, faster reaction time, enhanced fetal health, and a reduction in the risk of a variety of other disorders. Such foods have become a source of hope for good health, with solid evidence that they are useful for their intended purposes when taken as part of a well-balanced, healthy diet.

13.2 Recommendations

So long as the notion of functional foods is widely accepted, plant-derived functional foods, beverages, and components will play a significant part in human nutrition. Governments around the world should stimulate the formation of firms dedicated to the study and development of bioactive-rich foods with potential health benefits beyond basic nutrition due to budgetary restrictions. According to food scientists and technologists, functional foods require in vitro, in vivo (animals), and clinical testing to verify any health claims, without which the generated product is simply nutritious rather than functional. Food scientists should collaborate with professionals from many fields to establish a holistic picture of foods and explore their impact on human metabolism. Forming a solid connection between research, technology, and health is the most effective way to understand and create functional foods. New extraction and processing processes for bioactive plant constituents, as well as experimental settings, should be used to improve yield and chemical stability of these bioactive chemicals. A novel investigation should be conducted that focuses on the use of underused plant-derived bioactive chemicals in diverse food matrices and their effects on sensory, physicochemical, rheological, and functional aspects. Understanding the relationships between plant-derived functional bioactive compounds and their dosage, safety, stability, delivery systems, and price, as well as exploring the functional food market from a technological and marketing standpoint, with recent scientific advances in mind, is still a long way off.

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