

**Formulation of Beta Carotene and Fibre Rich Nutritious Bar Using
Sweet Potato (*Ipomoea batatas*) and Millets**

BY

ABINAYA.GP

(20PFN001)

THESIS SUBMITTED TO



**AVINASHILINGAM INSTITUTE FOR HOME SCIENCE AND HIGHER EDUCATION
FOR WOMEN**

COIMBATORE-641043

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE IN FOOD SCIENCE AND NUTRITION**

May 2022

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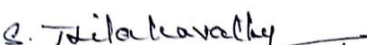
May 2022


S. Thilakavathy
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Signature of the Head of the Department

DECLARATION

I hereby declare that the dissertation entitled “**Formulation of Beta Carotene and Fibre Rich Nutritious Bar Using Sweet Potato (*Ipomoea batatas*) and Millets**”, submitted to the Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, in partial fulfilment of the requirement for the award of the **Degree of Master of Science in Food Science and Nutrition** is a record of original research work done by me under the supervision and guidance of **Dr.(Mrs.) S.Thilakavathy,M.Sc.,M.Phil.,Ph.D**, Assistant Professor(SG), Department of Food Science and Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore and that it has not formed the basis for the award of any Degree/ Diploma/ Associateship /Fellowship or similar title to any candidate of any other University and it represents entirely an independent work on the part of the Candidate.


Signature of the Supervisor 26/05/2022


Signature of the Candidate

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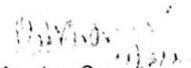
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Introduction

I. INTRODUCTION

Nutritional quality of food is the most important parameter for maintaining human health and complete physical well-being. Nutritional well-being is the driving force for development and maximization of human genetic potential and dietary quality of food should be taken into consideration for maintaining overall maximization of human health and fitness to solve the problem of deep-rooted malnutrition (Sarita and Singh, 2016). According to the World Bank report, about 815 million people worldwide are facing the problem of hunger and malnutrition. This is one of the major issues in developing countries as they are not getting enough food, and their food deficiency results in illnesses and deaths worldwide. However, specific attention to the nutritional quality and cultivation of millets can provide an overall solution to the existing challenges of hunger and malnutrition. (Yousaf *et al.*,2021)

Nutrition is an indispensable part of human life, which is inevitable for leading a healthy life. Nutrients are usually categorized into macronutrients and micronutrients. Macronutrients are those nutrients, which our body needs in large amounts including fats, proteins, and carbohydrates. Micronutrients are needed in smaller amounts, which includes several vitamins and minerals. The quantity of micronutrients required in a balanced diet are very low yet they have a profound impact on the physical and mental growth of a person. Vitamin A, an important micronutrient is necessary for the regulation of various bodily functions such as growth, vision, reproduction, morphogenesis, immunity, normal cell growth, immunological functions and vision. Vitamin A plays a major role in various biological phenomenon and it cannot be produced naturally in human body, hence it must be consumed through the diet.(Kundu *et al.*, 2021)

Vitamin A deficiency is the leading cause of preventable childhood blindness and increases the risk of death from common childhood illnesses such as diarrhoea (UNICEF, 2019). It is recognized as a public health issue in developing and underdeveloped countries. Children are the most vulnerable and are easily prone to vitamin A deficiencies due to reduced dietary intake and poor absorption leading to depleted vitamin A stores in the body. Factors that add fuel to the issue are a high incidence of infectious diseases like diarrhoea, worm infestations, measles, other respiratory diseases (Rajya Lakshmi Devi and Thilakavathy,2021)

There are two main sources of vitamin A: animal sources and plant sources. All the sources of vitamin A need some fat in the diet to aid absorption. In animal sources, vitamin A is found as retinol, the 'active' form of vitamin A. Liver, including fish liver, is a very good source. Plant sources of vitamin A present in the form of beta carotene include: mangoes, papaya, many of the squashes, carrots, sweet potatoes and maize (but not the white varieties). Ultraviolet light can also reduce the

vitamin A content of food, so drying of fruits such as mangos should not be done in direct sunlight.(Gilbert,2013)

Vitamin A deficiency is generally associated with decreased dietary intake of preformed vitamin A and its precursors, together with a high prevalence of infectious diseases, like measles, diarrhoea, and respiratory tract infections. Diets containing insufficient vitamin A leads to decreased serum vitamin A levels, resulting in various physiological implications, especially tissue development, metabolism, and resistance to infections. Lower vitamin A levels were reported in the breastmilk of mothers with VAD; therefore, nursing mothers with VAD transferred relatively lower concentration of vitamin A to the infants through breastfeeding. (Akhtar *et al.*,2013)

Various international efforts are being made since long back for alleviating vitamin A deficiency and thereby combating night blindness. Among three different approaches, namely supplementation programme through distribution of vitamin capsules; fortification of common foods with micronutrients and the improvement of dietary quality through diversification of foods, the third one is an important food-based approach in achieving and maintaining adequate intake of micronutrient-rich foods in the context of an adequate total diet. Food based approaches requires an inter-sectoral perspective like providing agricultural and educational inputs with an awareness of cultural, socio-economic, market and health conditions which may prove to be the most sustainable of the various interventions. Introduction of new crops and home gardening have also been proved to be the most important components of food-based approach in improving both dietary quality and quantity.(Mitra,2012)

Root and tuber crops play a significant role in agriculture and facilitate food security in many developing countries. Among the roots and tubers, Sweet Potato (*Ipomoea batatas*) is very important after potato on the basis of production and consumption. Sweet potato considered as the food security crop due to its low agriculture input requirements and high yields in wider climatic conditions (Neela and Fanta,2019)

Sweet potato (*Ipomoea batatas*) is a dicotyledonous angiosperm plant which belongs to the Convolvulaceae family and its capable of producing nutritious tuberous roots eaten worldwide. According to data made available by the Food and Agriculture Organization (FAO), in 2018, more than 91 million tons of sweet potatoes were produced worldwide (Cartabiano-Leite ,2020). The sweet potato (*Ipomoea batatas*) is a starch crop with high potential to meet the food and nutrition security needs for a sustainable society in the twenty-first century. (Kwak, 2019).

The orange- fleshed sweet potato being rich in β -carotene is gaining importance as the cheapest source of antioxidant having several physiological attributes like antioxidant, anti-cancer and protection against liver injury and is most suiting as biofortified crop to combat malnutrition in small and marginal farming community. (Gitanjali and Lakhawat, 2018). The Hannah sweet potato without skin has the highest phenol compound(1285.25mcg/ml). The Oriental sweet potato has an flavonoid content of 293.28mcg/ml. Even though sweet potato is a good source of carbohydrates (20%), the World Health Food Organization (WHFO) has acknowledged as the root crop with “antidiabetic” activity. (Anbuselvi *et al.*,2012)

Sweet potato is a typical food security crop because it can be harvested little by little over several months. It is because of these unique features and nutritional value of the sweet potato that the National Aeronautics and Space Administration (NASA) has selected it as a candidate crop to be grown and incorporated into the menus for astronauts on space missions. (Chandrasekara and Josheph,2016). Different polyphenolic compounds have been isolated and identified by chromatography from extracts of sweet potato flour. The identified compounds were stated to possess impressive pharmacological properties including hepatoprotective and antihistamine properties. (Grebla-Al-Zaben *et al.*,2021)

Sweet potato flour plays a pivotal role in the preparation of various food items, which can boost consumer nutritional and health status. Recently, the use of sweet potato flours as an ingredient for functional foods has garnered significant interest. Sweet potato flour has become a key solution for the production of new products in the current global habitation. It has a high-energy, low-protein, and has been reported to be of good biological value. It has been found to contain a high source of β -carotene. Imperative content of nutrients that found in sweet potato flours plays a pivotal role in sustaining main food products developments and also can make it to be used as an ingredient in the numerous food formulations. (Dereje *et al.*,2020)

Millets are known as one of the most important cereal grains as it is good source of phytochemicals and micronutrients. Millets are consumed by more than 1/3rd of the world’s population. It is the 6th cereal crop in terms of world’s agricultural production. They have been cultivated for a thousand years and are used throughout the world. Millets are rich in phytochemicals like phenolics, sterols, lignans, inulin, resistant starch, β -glucan, phytates, tocopherol, dietary fiber and carotenoids. (Jahan *et al.*,2020).

As per the FAOSTAT, global millet production for the year 2019 was 27.8 million tonnes. India is the largest global producer with a 41.0 % global market share. (Sharma *et al.*,2020). Millets are grown in India since many years and the most important millets are pearl millet, finger millet,

proso millet and foxtail millet. According to FAO, the most important cultivated millet species are: pearl Millet also known as bulrush millet; proso millet, also known as common millet; foxtail millet; Japanese barnyard millet; finger millet also known as birds food millet or African millet; and kodo millet of India. Other millets include little millet that promotes millets as nutri-cereals rather than coarse cereals. Millets are highly nutritious and provide protein, fiber, iron, B vitamin, manganese, phosphorus, potassium and magnesium. They are highly alkaline, making it easily digestible and soothing to the stomach. (Khan *et al.*,2019).

Proso millet is especially well suited to dry climates such as in Northern India. Foxtail millet is regarded as a native of China, it is one of the world's oldest cultivated crops. Little millet was domesticated in India. It is grown throughout India to a limited extent up to altitudes of 2100 m, but is of little importance elsewhere. (Dayakar Rao *et al.*,2017). Pearl millet, which accounts for about two-thirds of India's millet production, is grown in the dry areas of the country, mainly in the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana. Finger millet is produced mainly in the state of Karnataka, but also in Orissa, Uttar Pradesh and Tamil Nadu. The barnyard millet is grown mainly in Uttarakhand, Maharashtra and Tamil Nadu, both as fodder and for human consumption and has an amazing nutrition profile. Karnataka is one of the leading states in the production of millets. Millets do not demand chemical fertilizers. Most millet farmers grow them using farmyard manure under purely eco-friendly conditions and also started using biofertilizers such as vermicompost and growth promoters such as panchagavya, amritpani etc. These practices make millet production not only eco-friendly but stays under the control of farmers. (Changmei. and Dorothy,2014)

One of the major problems faced in our country is micro nutrient deficiencies. It can be combated by the cheapest, easiest and best way by the process of fortification. Bio fortified millets have a great potential to reduce micronutrient deficiency in the developing countries. Millets being less expensive compared to other cereals could be chosen as the best vehicle for fortification. In millets, micronutrient such as iron, zinc, calcium and vitamins can be used as fortificants .Millets are more nutritious than refined flour therefore can be incorporated into bakery products as well and it is slowly used in some of the bakery outlets. To combat zinc deficiency, finger millet flour can effectively be used as a vehicle for zinc fortification to derive additional amounts of bio-accessible zinc, with reasonably good storage stability. Fortification of staple foods with minerals like iron and zinc are one of the cost-effective methods to combat the micro nutrient deficiencies. (Thakur and Tiwari,2019)

Sprouting of the millets enhances the digestibility and causes increased activities of hydrolytic enzymes like lipase, improvements in the contents of total proteins, fat, essential amino acids, total

sugars, B-group vitamins and starch digestibility and decrease in phytates and protease inhibitors. (Dipnaik and Bathere ,2017). Popping of cereals has been practised since hundreds of years. Popping of millet grains invariably improves taste and flavour. The popping not only improves the shelf-life but also improves the nutritional quality with respect to bioavailability of nutrients.(Kumari *et al.*,2018)

Due to specific bioactive constituents and other important nutrient components (protein, fiber and minerals) millets flour can be used for incorporation in food preparations. Addition of millet could improve the texture, taste and colour of final preparation. Fortified products prepared from millets flour not only improve the sensory characteristics but also control the glucose level in blood of patients suffering from diabetes. Changing life style and food related habits of peoples create a demand for nutritious food products with varying sensory features. (Kaur *et al.*,2018). Cereal based snack bars are small rectangular nutritional food bars with a weight of 25–50 g and these days nutritional bars have become popular and exist in several types of cereal-based snack bars such as high-protein, high-fibre and high-calorie bars. These bars offer a fast, appropriate food source requiring modest preparation, with long shelf life and no refrigeration requirements. (Singh *et al.*,2021)

Due to the growing consumer demand in consuming nutritious food products and various beneficial aspects of sweet potato and millets, the oriental and Hannah variety of sweet potato flour was incorporated into the different millet bars. Barnyard millet bar, foxtail millet bar, Pearl millet bar, Finger millet bar and sorghum millet bar were prepared and to these millet bars sweet potato flours was incorporated at various levels and their acceptability was tried out.

Hence the present study entitled – Formulation of Beta Carotene and Fibre Rich Nutritious Bar Using Sweet Potato (*Ipomoea batatas*) and Millets was conducted with the following objectives:

- To prepare fibre rich millet bars by incorporating sweet potato flour
- To analyse the functional properties, phytochemicals and nutrients present in the Oriental and Hannah varieties of the sweet potato flour
- To analyse the organoleptic characteristics of different sweet potato millet bars prepared.
- To analyse the microbial content, color, texture characteristics and shelf life of the prepared sweet potato millet bars.

Review of Literature

II. REVIEW OF LITERATURE

The Review of literature pertaining to the study entitled - Formulation of Beta Carotene and Fibre Rich Nutritious Bar Using Sweet Potato (*Ipomoea batatas*) and Millets is presented under the following headings:

- I. Prevalence of vitamin A deficiency in India
- II. Bioactive Compounds of Sweet Potato and Millets
- III. Therapeutic properties of Sweet Potato and Millets
 - A. Sweet potato
 - B. Millets
 - i. Barnyard millet
 - ii. Foxtail millet
 - iii. Ragi
 - iv. Bajra
 - v. Jowar
- IV. Value added products from sweet potato
- V. Millet bars

I. Prevalence of vitamin A deficiency in India

Vitamin A is an essential nutrient that must be provided in the diet as it cannot be synthesized by humans. Young children are more vulnerable to its deficiency. In low- to middle-income countries such as India, it is widely accepted that micronutrient deficiencies are highly prevalent because of inadequate dietary intake, infections and chronic inflammation, which could lead to poor absorption of the nutrient or increased catabolism. The primary assessment of population Vitamin A deficiency is performed by examining for signs of clinical deficiency and serum retinol concentrations, which is a status biomarker. The Comprehensive National Nutrition Survey (CNNS, 2016– 2018) now offers this primary evidence for assessing Vitamin A deficiency across India in 1-5year old children. The requirement of vitamin A in India is presently available only as a single value called the RDA, while measuring the risk of dietary inadequacy requires definition of the requirement distribution and the average requirement. (Reddy *et al.*,2021).

Vitamin A affects around 19 million pregnant women. It is considered a public health issue in many developing countries. Maternal vitamin A deficiency is possibly one of the main causes of foetal growth restriction and of the subsequent risk of insulin resistance and glucose intolerance in adulthood (Bastos Maia *et al .*, 2019) and it is estimated that globally about 30% of children < 5 years

of age are vitamin A deficient, and about 2% of all deaths are attributable to Vitamin A deficiency in this age group. Vitamin A deficiency is also a major cause of preventable childhood blindness. (Wirth *et al.*, 2017)

According to the study by Reddy *et al.* (2022) the prevalence of Vitamin A deficiency was measured by serum retinol concentrations from data collected from the Comprehensive National Nutrition Survey (CNNS 2016-18). The Serum retinol concentrations increased with age (5–19 years) in both genders and were significantly lower in school age children (1.02 $\mu\text{mol/L}$) compared to adolescents (1.13 $\mu\text{mol/L}$). The prevalence of Vitamin A deficiency was significantly higher among children with lower socio-economic status.

II. Bioactive Compounds of Sweet Potato and Millets

Sweet Potato

National Institutes of Health defines bioactive compounds as constituents in foods or dietary supplements, other than those needed to meet basic human nutritional needs, are responsible for changes in health. (Weaver, 2014). Earlier research studies have pointed out that bioactive compounds are different in orange-fleshed sweet potato and white fleshed sweet potato. Phytochemical screening conducted by Shekar *et al.* (2015) revealed high percentage of carbohydrate, reducing sugar, and phenolics in white fleshed sweet potato and increased levels of total protein, flavonoids, anthocyanins and carotenoids in orange-fleshed sweet potato. Phenolic compounds and carotenoids have been reported to be present in sweet potatoes. Sweet potatoes are an abundant source of dietary fiber, minerals, vitamins, beta-carotene, phenolic acids, and anthocyanins. These bioactive compounds confer distinctive flesh colors to sweet potatoes such as cream, yellow, orange, and purple. The major bioactive compounds that are generally present in sweet potato are flavonoids, terpenoids, tannins, saponins, glycosides, alkaloids, steroids and phenolic acids. These constituents may vary with varieties depending on flesh and skin colours. (Kulczynski *et al.*, 2016).

Carotenoids as antioxidants have also been reported to have preventive effects for some diseases in vitro and in animal models. The carotenoid contents ranged from 1.3 mg/100 g to 3.9 mg/100 g dry weight in yellow-fleshed cultivars. The main carotenoids were β -carotene 5,8;5',8'-diepoxide (approx. 32%–51%) and β -cryptoxanthin 5',8'-epoxide (approx. 11%–30%) in the yellow-fleshed cultivars. The carotenoid component in the yellow and orange flesh are almost identical. These carotenoids showed anti-oxidative activities. (Tanaka *et al.*, 2017). An increase in β -carotene plasma level was observed when 8 mg of β -carotene was ingested with increasing amounts of fat (from 3 g to 36 g). These observations suggested that a minimum threshold of dietary fat is required to facilitate the absorption of β -carotene (3 g of dietary fat for 8 mg β -carotene (Maurya *et al.*, 2020)

The different varieties of sweet potatoes with the same flesh color may differ in total phenolic content, individual phenolic acid profile and antioxidant activity. (Andre *et al.*, 2018). Alkaloids, phenolic compounds, and glycolipids are the most common biologically active constituents of *Ipomoea batatas*. Different polyphenolic compounds 4-O-caffeoylquinic acid, 1,3-di-O-caffeoylquinic acid and 3,5-di-O-caffeoylquinic acid, possessing potent anti-oxidant activities, have been isolated by chromatographic methods from methanolic and hydro methanolic extracts of I. batatas tuber flour.(Mohanraj and Sivasankar,2014)

Sweet potato roots are used in folk remedies to treat illnesses as diverse as asthma, night blindness and diarrhoea. Choline present in sweet potatoes helps to maintain the structure of cellular membranes, aids in the transmission of nerve impulses, assists in the absorption of fat and reduces chronic inflammation. The vitamin A in sweet potatoes (consumed as beta-carotene then converted to vitamin A in the body) is also essential for hormone synthesis during pregnancy and lactation (Rajya Lakshmi Devi Yenmula & Thilakavathy,2018)

Millets

In the past few decades, considerable effort is being devoted to finding new sources of medicines, but ancient food resources which provide therapeutic benefits are not being extensively explored. As compared to the three major cereal grains of the world, namely, wheat, rice and maize, millets not only provide the highest number of calories following wheat and rice, but also supplement the diet with micronutrients, essential amino acids, polyphenols, avenanthramides, flavonoids, polycyanins, lignins and polysterols.(Prasad *et al.*,2020)

Several studies have shown that millets also have a broad range of bioactive phytochemicals that are beneficial to human health. Notable among these phytochemicals are polyphenols. Polyphenols often act as antioxidants within the human body to protect against oxidative stress and to reduce the risk of non-communicable diseases. (Kumari *et al.*,2017). Other bioactive properties of polyphenols include anticarcinogenic, anti-inflammatory, antiviral and neuroprotective activities. Millet polyphenols are involved in the inhibition of amylase and glucosidase that lead to a decrease in postprandial hyperglycaemia (Akanbi *et al.*,2019)

Millets contain mainly free and conjugated forms of phenolic acids, which include derivatives of hydroxybenzoic and hydroxycinnamic acids. In addition, several flavonoids, namely anthocyanidins, flavanols, flavones, flavanones, chalcones, and amino phenolic compounds are found in millets. Several hydroxybenzoic acids, namely gallic, protocatechuic, p-hydroxybenzoic, gentisic, vanillic, and syringic have been identified in whole millet grains. (Chandrasekara and Shahidi ,2013)

Flavonoids are the main class of polyphenols, the basic chemical structure which contains a heterocyclic C6-C3-C6 skeleton. Flavonoids are prominent component of millets. Dietary flavonoids are considered to be even more powerful antioxidants than vitamins C and E (Nithiyantham *et al.*,2019). The commonly found flavonoids in millets are catechin, quercetin, luteolin, orientin, apigenin, isoorientin, vitexin, myricetin, isovitexin, daidzein, violanthin, lucenin-1, and tricetin (Pradeep and Sreerama,2017). Millets flavonoids have shown a wide range of therapeutic properties for medical and clinical applications, such as anti-inflammatory, antihypertensive, diuretic, analgesic, anticancer and hypolipidemic effects. (Ekta and Sarita,2016)

Carotenoids are well known for their provitamin-A activity. However, carotenoids are among those important compounds which protect against various diseases because they act as antioxidants. Phytosterols are desmethyl sterols are essential structural and functional components of plant cells. Phytosterol esters have the potential to reduce blood serum LDL cholesterol levels up to 14% but no effect on HDL levels. (Himanshu *et al.*,2018)

III. Therapeutic properties of Sweet Potato and Millets

A. Sweet potatoes

Sweet potatoes are especially significant because of their abundant nutraceutical components. This tuberous root is a rich source of carbohydrates, dietary fiber, vitamin A (as β -carotene), vitamin B6, vitamin C, manganese, copper, potassium, and iron. Sweet potatoes offer a near-balanced diet for the human body in that they possess significant amounts of carbohydrates in comparison with other starchy foods such as rice, maize, and sorghum porridge. In the class of different varieties of sweet potatoes, orange-fleshed sweet potato is reported to possess high amounts of β -carotene, a precursor for vitamin A. It has been recorded that the amount of β -carotene is directly proportional to the intensity of orange color of the sweet potato flesh. (Mohanraj,2017)

Many studies have reported different medicinal potentials of sweet potato. These properties have been attributed to either a single or combined effect of the phytochemicals present in the plant. In traditional medicine, sweet potato has been used to treat many diseases such as oral infections, inflammatory diseases (Anbuselvi and Balamurugan,2014) and also in the management of diabetic conditions (Dutta ,2015).

Phytochemicals such as flavonoids and related phenolic compounds which are generally present in sweet potatoes have been reported to have multiple biological effects, such as antioxidant activity. Many evidences suggest that degenerative diseases such as cancer, asthma, diabetes, senile dementia and eye disease have their origin in deleterious free radical reactions. There are studies that

have suggested that sweet potato has the potential of lowering the blood glucose level. Generally, the anti-diabetic property of sweet potato has been attributed to its phytochemical content. (Ayeleso *et al.*,2017)

Cardiovascular diseases (CVDs) have spread across the world, and their prevalence is on the rise (Tang *et al.*, 2017). Sweet potato's anti-inflammatory properties makes it a good food for appraisal as a natural remedy for preventing and controlling inflammatory diseases. High fiber content of sweet potatoes aids in preserving water in the body. Magnesium, which is found in sweet potato, helps with digestion as well. In treating stomach ulcers, B-complex vitamins, vitamin C, β -carotene, potassium, and calcium found in sweet potato are helpful. In addition, fiber in sweet potato alleviates constipation and the associated formation of acid, which decreases the risk of ulcers. (Alam,2021)

B. Millets

i. Barnyard Millet

Barnyard millet grains are a rich source of dietary fiber, iron, zinc, calcium, protein, magnesium, fat, vitamins, and some essential amino acids. The high ratio of carbohydrate to crude fiber ensures the slower release of sugars in the blood, and so thus aids in maintaining blood sugar level. The resistant starch in barnyard millet has shown to lower blood glucose, serum cholesterol, and triglycerides in rats. In addition, a lower phytate (3.30–3.70 mg/100 g) content in grains followed by the dehulling process has also decreased phytic acids significantly, favouring the bioavailability of minerals. (Renganathan *et al.*,2020)

The polyphenols and carotenoids are known to have several potential benefits to humans, and are twofold higher in barnyard millet than finger millet (Panwar *et al.*, 2016).The alkaloids, steroids, carbohydrates, glycosides, tannins, phenols and flavonoids present in barnyard millet have various ethno-medical properties like being antioxidant, anti-carcinogenic, anti-inflammatory, antimicrobial, having a wound healing capacity, biliousness, and alleviating constipation associated diseases.(Sharma *et al.*, 2016).

ii. Foxtail Millet

Foxtail millet, like most millets, is also a good source of crude fiber, helps in the digestive process and helps to induce bowl movement, thus producing a laxative effect that is beneficial for a healthy digestive system. In addition to its nutritional properties, foxtail millet has also shown to possess several health benefits like prevention of cancer, hypoglycemic, and hypolipidemic effects. (Zhang, 2015)

Foxtail millet protein hydrolysates were found to have antioxidant activity and even the carotenoids, mainly all-trans-lutein and all-trans-zeaxanthin are believed to impart yellow color to the foxtail millet grains, can exert antioxidant effect. (Sharma and Niranjana,2018).Dietary fibers in foxtail

millet help in aiding gastrointestinal functions and decreasing the postprandial hike in serum glucose concentrations with a modest effect on the serum cholesterol concentrations. (Bangoura *et al.*,2013)

iii. Finger Millet

Finger millet or ragi is one of the ancient millets in India (2300 BC). Finger millet is exceptionally rich in calcium (344 mg%) compared to all other cereals and millets (eightfold higher than pearl millet) and contains 283 mg% phosphorus, 3.9 mg% iron, and many other trace elements and vitamins. The bioaccessibility of minerals like iron and manganese were increased on malting of finger millet and popping of finger millet decreased the bioaccessibility of calcium but increased the bioaccessibility of iron and zinc. (Shobana *et al.*,2013)

Finger millet grains contain 44.7% of essential amino acids including methionine, cysteine and tryptophan, lysine, isoleucine, leucine and phenylalanine as well as threonine which helps to lower cholesterol levels and reduce risk of cancer and obesity in the human body. Tannins in the outer layer of the grain, serves as a physical barrier to fungal invasion. (Ramashia *et al.*,2019). Other benefits of finger millet are development and repair of body tissue, prevention of gallstones, protection against breast cancer and protection against postmenopausal women and childhood cancer. (Verma & Patel, 2013)

Three classes of phenolic found in finger millet- hydroxybenzoic acid derivatives, hydroxycinnamic acid derivatives and flavonoids. High dietary fiber and phenolic content makes finger millet very beneficial for diabetic patients. Finger millet is a highly nutritive cereal and has long been used as a remedy for many infections including the leukemia. Finger millet incorporated diet prevents mucosal ulceration. Germinated finger millet-based food showed a general improvement on haemoglobin status. (Chandra *et al.*,2016)

iv. Pearl Millet

Pearl millet grains possess considerable amounts of proteins, fat, carbohydrate, minerals, vitamins and phytochemicals. Wide prospective health advantages of pearl millet have been reported, such as prevention of cancer and heart diseases, reduction in the occurrences of tumor, high blood pressure, cholesterol and fat absorption rates, delay in gastric emptying and providing gastrointestinal bulk. As pearl millet lacks gluten, the people who are allergic to gluten and suffering from celiac disease can choose it as a nutritious alternative to other cereals. (Shobhit *et al.*,2020).

V. Sorghum

Sorghum is an important global cereal crop with very high nutritional and health value. Incorporating sorghum into the mainstream diet could help to prevent obesity and diabetes and improve human health status. Studies have shown that sorghum phenolic compounds have potent antioxidant activity in vitro, and consumption of sorghum whole grain may improve gut health and reduce the risks

of chronic diseases. Evidence has been shown that sorghum possesses potential antioxidant, anti-inflammatory, and anticancer activities, and could improve glycemic response and insulin-related disorders, prevent dyslipidemia and cardiovascular diseases, and influence gut microbiota and promote colonic health. (Xiong *et al.*,2019)

In vitro and animal studies have shown that the lipidic and phenolic fractions from sorghum modulate parameters related to dyslipidemia and the risk of cardiovascular disease. These benefits result from the action of phytosterols and phenolic compounds, which may modulate absorption, excretion, and synthesis of cholesterol. (De Morais Cardoso *et al.*,2017)

IV. Value Added Products from Sweet Potato

A. Sweet Potato Ketchup

Sweet potato ketchup consists of 32.3% (w/v) sweet potato, 42% water, 12.9% vinegar, 11.3% sugar, 1.0% salt and 0.3% spices. The roots are washed, trimmed, chopped into chunks, and boiled. The boiled chunks are blended with water and other ingredients and boiled to the desired consistency before bottling. Various sweet potatoes which range from yellow to orange and which have a moist texture can be used for ketchup making. Sweet potato ketchup had viscosity, pH, total soluble solids, and intermediate vitamin A content comparable to values found in banana ketchup. (Oke & Workneh,2013)

B. Sweet Potato Noodles and Other Extruded Foods

Sweet potato is processed into noodles in many countries and there are many home scale and cottage level processing units which make traditional noodles from sweet potato starch. The process consists in gelatinizing sweet potato starch slurry in a big vessel at 80°C, treating with sulphate to prevent discoloration and mixing with native dry sweet potato starch to form a dough. The dough is then filled to long cylindrical column and pressed to extrude the dough into strings into hot water. This is then separated manually to prevent adhesion. The strings are then suddenly put to cold water, when the outside hardens and stickiness is reduced. The noodles are then dried slowly so that both inside and outside get dry. (Padmaja *et al.*,2012)

VI. Millet Bars

Recently, the consumption of fast-foods and snacks has increased, the desire for healthy and functional foods is also increasing at the same rate. Traditionally, snack foods appeal to consumers on a number of levels such as taste, appearance, texture etc. Carefully designed nutritious snacks could help in decreasing under-nutrition problem and can provide an increased dietary intake of fibers, essential amino acids and other nutrients for developing countries. Busy life styles and the increasing demand from consumers for meals and snacks that are quick sources of good nutrition have prompted the food

industry to develop foods like nutrition bars that combine convenience and nutrition. Accordingly, cereal bars emerged about a decade ago and represent an alternative food that is easy to consume while simultaneously possessing functional properties. (Sharma *et al.*,2014)

Increased health consciousness and changes in lifestyle coupled with awareness about the benefits associated with wellness food have led to significant changes in consumer behaviour toward healthy food consumption in the recent years. More than half of men and women are reported to consider nutritional factors such as fiber, vitamins, and sugar content when purchasing RTE cereals. (Smitha and Nandakumar,2020).

The busy life and accumulated shopper demand for healthy snacks had created a chance for the development of nutrient dense nutri-bars that are convenient and ready to use. Millets provide macronutrients and phytochemicals and hence, are often substituted with cereals due to functionality in improving health of consumers. (Himaja. and Meera,2020). Modified Sweet Potato flour can be used in the making of the snack bar but utilization of sweet potato is limited to their traditional uses. Development of low and intermediate technologies that will process sweet potato into value added products at the household and village factory levels would promote its production and consumption and increase its economic value. (Sohail *et al.*,2013).

Methodology

III. METHODOLOGY

The methodology pertaining to the study on “Formulation of Beta carotene and Fibre Rich Nutritious Bar Using Sweet Potato (*Ipomoea batatas*) and Millets comprised of the following phases:

Phase I: Selection and collection of Oriental and Hannah variety of sweet potatoes

- A. Selection and Collection of Oriental and Hannah varieties of sweet potatoes
- B. Processing of Oriental and Hannah varieties of sweet potatoes

Phase II: Determination of functional properties, analysis of phytochemicals and nutrients of the oriental and hannah variety of sweet potato flour

- A. Determination of functional properties of Oriental and Hannah varieties of sweet potato flour
- B. Analysing the Phytochemical compounds present in Oriental and Hannah varieties of sweet potato flour
- C. Analysing the nutrients present in Oriental and Hannah varieties of sweet potato flour

Phase III: Formulation and standardization of millet bars incorporating Oriental and Hannah sweet potato flour

- A. Selection of ingredients for development of Oriental and Hannah variety sweet potato flour incorporated millet bars
- B. Processing of the selected ingredients
- C. Formulation and standardization of millet bars incorporating Oriental and Hannah sweet potato flour
 - i. Sprouted barnyard millet bars incorporating oriental and hannah sweet potato flour
 - ii. Sprouted foxtail millet bars incorporating oriental and hannah sweet potato flour
 - iii. Popped finger millet bars incorporating oriental and hannah sweet potato flour
 - iv. Popped pearl millet bars incorporating oriental and hannah sweet potato flour
 - v. Popped sorghum millet bars incorporating oriental and hannah sweet potato flour
- C. Organoleptic evaluation of the developed products

Phase IV: Nutrient Analysis of the Oriental sweet potato flour incorporated millet bars

- A. Analysing the nutrients present in oriental sweet potato flour incorporated millet bars

Phase V: Microbial analysis, Color analysis, Texture characteristics and shelf - life testing of the products developed out of Oriental and Hannah sweet potato flour

- A. Analysing the microbial content, colour, texture characteristics and shelf-life of all the products developed out of Oriental and Hannah variety of sweet potato flour

Phase I: Selection and collection of Oriental and Hannah variety of sweet potato

The research study and the protocols used in the research was presented to the Institutional Ethical Committee and Ethical Clearance was obtained and it is presented in Appendix I. The approval number given by the ethical committee is A UW/IHEC/FSN-21-22/XPD-01.

A. Selection and Collection of Oriental and Hannah varieties of sweet potato

Sweet potatoes were introduced to countries like India between the 14th and 16th century, and its intensive cultivation began ~630 years ago in Asia. Sweet potatoes are rich in essential minerals like Mg, Mn, Fe, P, Zn, Cu Ca and vitamins, such as β - carotene, lutein, vitamin B1, B2, B6, pantothenic acid, niacin, biotin. Sweet potatoes are recognized as an excellent source of provitamin A. Sweet potatoes phytochemicals help to prevent many illnesses including certain types of cancers and cardiovascular disorders. In addition to the nutritional benefits sweet potatoes contain a wide range of phytochemicals with antioxidant capacity (flavonoids), xerophthalmia(carotenoids)among other health benefits.(Escobar-Puentes *et al.*,2022)

The Oriental sweet potato with pink colour peel with yellow flesh and the Hannah sweet potato with brown colour with white flesh were selected for the development of sweet potato millet bars. The deeper the color of the sweet potato, the richer is the beta carotene content present in it. Small to medium sized firm sweet potatoes with smooth skin and no bruises or cracks were chosen. The Oriental and Hannah variety of sweet potato were collected from local area of Saibaba colony, Coimbatore.

B. Processing of Oriental and Hannah varieties of sweet potato

Sweet potato is a major root crop utilized widely for diverse food applications. Keeping and handling of this commodity pose serious spoilage problems, owing to its high moisture, fragility, and pest-attractive nature. Processing of sweet potatoes assures better usability of the root as a food and it also enables the usability of sweet potato in various forms for longer durations. (Vithu *et al.*,2019)

1) Cleaning, Peeling, Slicing and Pre-treatment

Cleaning removes the dirt, organic matter and chemical residues adhering on the sweet potatoes and reduces the chances of spoilage. Both the varieties of sweet potato were washed well in running tap water to remove the dirt and sand particles. The clean tubers were peeled manually using vegetable peeler and sliced using a slicer. Slicing is usually accompanied by the color change (browning), so the peeled and sliced sweet potatoes were pre-treated with 100ml water with 0.1% citric acid for 10minutes to arrest the enzymatic browning and the slices were steam blanched for 2 minutes as steam blanching of sweet potato helps in higher retention of color and nutrients (Marangoni Junior *et al.*,2019). After the pretreatment process, the sweet potato slices were subjected to the drying process.

Mechanical Drying

Drying is removing a large portion of the water contained in a product in order to considerably reduce the reactions which leads to deterioration of the products. (Inyang, 2017). The pre-treated sweet potato slices were dried in a cabinet drier. The dehydration conditions such as drying temperatures, drying time and air velocity can be controlled in the cabinet driers. The sliced sweet potatoes are spread uniformly in a tray and were dried at 45°C for 6 hours. After the complete drying of the sweet potato slices it was powdered with the help of pulverizer. The powdered flour was sieved to remove any coarse particles to obtain fine powder of the flour. The powdered flour was stored in air tight containers. The phytochemical compounds and nutrients of the sweet potato flours were analysed in the laboratory. Figure 1 represents the flowchart for the preparation of oriental and Hannah sweet potato flour:

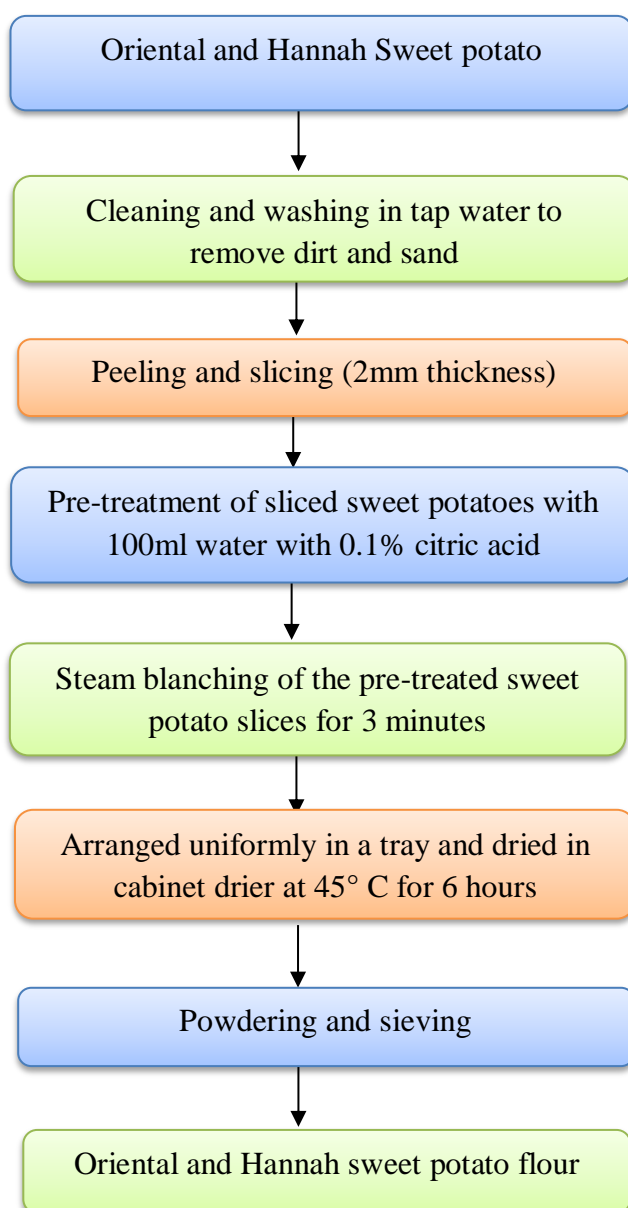


Figure 1: Flow chart for preparation of oriental and Hannah sweet potato flour

Phase II: Determination of functional properties, analysis of phytochemicals and nutrients of the oriental and hannah variety of sweet potato flour

A. Determination of functional properties of Oriental and Hannah varieties of sweet potato flour

i) Water absorption capacity

The water absorption capacity of the Oriental and Hannah sweet potato flours were analyzed based on the protocol given by Sosulski *et al.* (1976). Two gram of flour sample was mixed with 20 mL distilled water and allowed to stand at room temperature ($30 \pm 2^\circ\text{C}$) for 30 min, then centrifuged for 30 min at 2000 rpm. The volume of decanted supernatant fluid was measured and volume of water retained/bound per gram of sample calculated. Water absorption capacity was expressed as gram of water held per gram of sample using the formula given below:

$$\text{Water absorption capacity} = \frac{\text{Water on the sediment (g)}}{\text{Weight of the sample(g)}}$$

ii) Oil absorption capacity

The oil absorption capacity of the Oriental and Hannah sweet potato flours was determined according to protocols given by Robertson *et al.* (2000). Twenty-five milliliters of commercial olive oil was added to 250 mg of dry sample, stirred, and left at room temperature for 1 hour. After centrifugation at 2000 rpm for 30 minutes, the residue was weighed. The oil absorption capacity was expressed as a gram of oil absorbed per gram of sample using the formula given below:

$$\text{Oil absorption capacity} = \frac{\text{Oil on the sediment (g)}}{\text{Weight of the sample(g)}}$$

iii) Swelling power

The swelling power of Oriental and Hannah sweet potato flours was determined based on protocols given by Leach *et al.* (1959). One gram of each sample was mixed with 10 ml distilled water in a centrifuge tube and heated at 80°C for 30 min. This was continually shaken during the heating period. After heating, the supernatant was centrifuged at 1000 rpm for 15 min. The supernatant was decanted and the weight of the paste was taken. The swelling power of the sample was calculated as:

$$\text{Swelling power} = \frac{\text{Weight of the paste (g)}}{\text{Weight of the sample(g)}}$$

B. Analysing the Phytochemical compounds present in Oriental and Hannah varieties of sweet potato flour

Phytochemicals (from the Greek word phyto, which means "plant") are physiologically active, naturally occurring chemical compounds found in plants that have health benefits for humans beyond those provided by macronutrients and micronutrients. The primary goal of phytonutrient analysis is to determine whether or not chemical ingredients are therapeutically active.

Qualitative analysis of phytochemical constituents of Oriental and Hannah varieties of sweet potato flour was carried out.

i. Extraction of sample for phytochemical analysis

For the ethanolic extracts, finely ground powdered samples of sweet potato(3g) was extracted with 30 ml acidified ethanol (1% conc. HCl in ethanol) using a three steps approach as follows: A 10 ml solvent was added to each flour sample in a conical flask and completely covered with aluminium foil. The samples were stirred for 2 hrs using magnetic stirrer, centrifuged in a 50 ml plastic centrifuged tube at 1900 rpm for 10minutes at room temperature and decanted. The supernatant and the residue was re-extracted in 10 ml of the solvent for 15minutes, centrifuged and decanted. The supernatant was kept again and the process was repeated the third time for 20 minutes. The supernatant was combined and stored in a glass bottle covered with aluminium foil and kept at 4°C in refrigerator until further analysis.

a) Test for Alkaloids

To 1 ml of extracts add 3-4 drops of 2% picric acid solution, presence of alkaloids was confirmed by the formation of orange colour.

b) Test for Flavonoids

To 1ml of the extract add conc.H₂SO₄, presence of flavonoid was confirmed by the formation of orange colour.

c)Test for Saponins

To 1 ml of extracts add 2 ml of distilled water in a test tube. The solution was shaken for 15 minutes observed for the stable persistent foam of about 0.5 to 1 cm layer indicated the presence of saponins.

d) Test for tannins (Braymer's test)

To one ml of test sample, 3ml of distilled water and 3 drops of ferric chloride solution was added.The appearance of blue-green colour confirmed the presence of tannins.

e) Test for terpenoids (Chloroform test)

5ml of test sample was mixed with 2ml of chloroform and 3ml of concentrated h₂so₄ was carefully added to form a layer. A reddish – brown colour coloration at the interface was formed to show positive results for the presence of terpenoids.

f) Test for anthraquinones (Borntranger's test)

To few ml of the filtrate add 10ml of 10% ammonia solution and shake vigorously for 30 seconds. The anthraquinones in the sample was confirmed by the presence of a pink , or violet or red coloured solution.

A. Analysing the nutrients present in Oriental and Hannah varieties of sweet potato flour

The practice of determining the nutritional content of foods and food items is known as nutrient analysis. A variety of certified procedures can be used to carry out the procedure. Nutrient analysis is an important element of analytical chemistry since it offers information about the chemical composition, processing, quality control, and contamination of the foods. There are a variety of certified methods used for performing nutritional analysis.

The different nutrients namely Energy, carbohydrate, protein, fat, fibre, calcium, iron, beta carotene and vitamin C of the selected Oriental and Hannah varieties of sweet potato flour were analysed in the laboratory.

1.Estimation of Moisture content

One gram of wet coconut and dry processed Coconut flour were accurately weighed in the Digital Moisture Analyzer (Model 120H, Shimadzu Corp, Japan) and dried at 200°C for 20 minutes and 8 minutes until the weight was constant. The percentage loss on drying of the test sample was automatically recorded. The analyses were performed in triplicates.

2. Determination of Total ash content

By continuous heating, the substance gets charred which can be used for the determination of minerals present.

3.Estimation of Total Energy Content

The principle behind the working of bomb calorimeter is based on the fact that a known weight of the sample completely burnt in the apparatus permits the heat developed by the combustion to be absorbed by a definite weight of water. By determining the rise in temperature, it is possible to calculate within close limits, the number of heat units liberated.

4.Estimation of Carbohydrate

The sample is treated with 80% alcohol to remove sugar and then starch is extracted with perchloric acid. In hot acidic medium starch is hydrolysed, to glucose and dehydrated to hydroxyl methyl furfural. This compound forms a green colour product with anthrone.

5.Estimation of Protein

The protein content of foods has been determined on the basis of total nitrogen content. Kjeldahl method has been almost universally applied to determine nitrogen content. Samples are digested with sulphuric acid in a macro kjeldahl flask when nitrogen gets converted to Ammonium

Sulphate. Ammonia is liberated by the action of strong alkali in a macrokjedahl steam distillation apparatus.

6.Estimation of Fat content

Ether extraction of the crude fat in vegetable products is carried out in a continuous extractor that is an apparatus in which the ether, after dissolving a portion of the fat of the material and discharging into the extraction flask, is volatilized, condensed and again allowed to act on the material. The steps in the process are repeated continuously and automatically until the extraction is complete. The soxhlet extraction used depends on the intermittent action of a glass syphon. The ether gradually condenses into the extraction tube containing the material until it rises to the top when it is discharged into the extraction flask.

7.Estimation of Crude Fibre

The term "crude fibre" ordinarily meant in agriculture and food analysis is the organic residue consisting largely of cellulose, that is left after other carbohydrates and proteins have been removed by successive treatment with boiling acids and alkalies. The crude fibre obtained in this way is not cellulose but contains distinct properties of hemicellulose, and nitrogenous substances. These however are not sufficient to prevent the results from being reasonably accurate and comparable.

8.Estimation of Beta Carotene

Carotene present is extracted with petroleum ether and the intensity of the color of the extract is compared with that of the standard solution using a colorimeter.

9.Estimation of Calcium

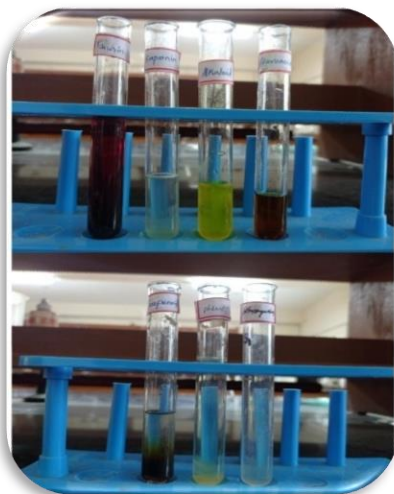
Calcium is determined by precipitating it as calcium oxalate and titrating the oxalate solution in dilute sulphuric acid against standard potassium permanganate.

10.Estimation of Iron

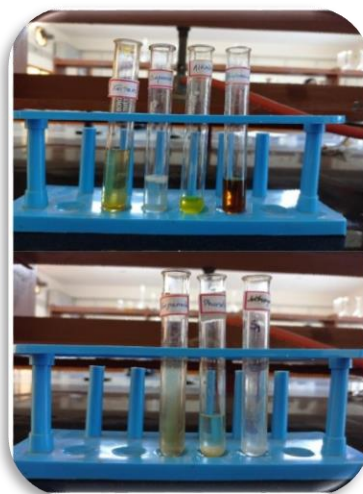
The food sample is oxidized with ignition or oxidation. Iron as ferric iron reacts with ammonium thiocyanate or with potassium thiocyanate to give ferric thiocyanate which is red in colour. The colour which is a measure of the concentration is measured colorimetrically.

11.Estimation of Vitamin C

Vitamin C is a good reducing agent and it reduces the dye 2,6 dichlorophenol indophenol. In this reaction, the ascorbic acid itself is oxidized to dehydro ascorbic acid. In the absence of interfering substances, the capacity of an extract of the sample to reduce a standard solution of the dye as determined by titration is directly proportional to the vitamin C content. Oxalic acid is not only used to reduce the pH of the extracting medium, thereby establishing vitamin C but also form complexes with metals eg. copper thereby preventing the catalytic oxidation of vitamin.



**Oriental sweet potato flour
ethanolic extracts**



**Hannah sweet potato
flour ethanolic extracts**



**Estimation of
Moisture content**



**Estimation of Ash
content**



**Determination of Energy
content**



Estimation of Fat content



Estimation of Calcium



Estimation of Iron



Estimation of Vitamin C

**ANALYSIS OF PHYTOCHEMICALS AND NUTRIENTS
PLATE I**

Phase III: Formulation and standardization of millet bars incorporating Oriental and Hannah sweet potato flour

A. Selection of ingredients for development of Oriental and Hannah variety sweet potato flour incorporated millet bars

Due to high therapeutic properties of sweet potatoes, it was incorporated into the various products. The ingredients which were selected for new product development are barnyard millet, foxtail millet, pearl millet, finger millet, sorghum, roasted groundnut, white sesame seeds, garden cress seeds, jaggery and dark chocolate.

1. Barnyard millet

Good quality barnyard grains were selected. The barnyard millet (*Echinochloa esculenta*) had 10.5% protein 3.6% fat, 68.8% carbohydrate and 398 kcal/100 g energy. The total dietary fibre content was high (12.6%) including soluble (4.2%) and insoluble (8.4%) fractions. Marginal decrease of triglycerides and increase of HDL were registered in diabetic groups due to barnyard millet intervention. (Ugare *et al.*,2014)

Barnyard millet was collected from the local stores of Townhall, Coimbatore.

2. Foxtail millet

The grains of foxtail millet (*Setaria italica*) which is small, ovoid in shape around 2mm long, pale yellow to orange in colour was selected. Grains of foxtail millet have low glycemic index and among the wide range of health promoting components, they are known to be rich in antioxidants, phenolics, dietary fiber, protein, fat, starch, vitamins and minerals. With abundant nutritional and health promoting components it is suggested that foxtail millet can be potential ingredient in food production. (Divakar and Prakash ,2021).

Foxtail millet was collected from the local stores of Townhall, Coimbatore.

3. Pearl millet

Pearl millet has been recommended for several therapeutic purposes, as it has been found to inhibit tumour development, control blood pressure and plasma low-density lipoprotein cholesterol levels and possesses anti-allergenic characteristics. Due to its high fibre content, pearl millet is also recommended for the treatment of severe constipation and stomach ulcers.(Raju *et al.*,2021)

Pearl millet was collected from the local stores of Townhall, Coimbatore.

4. Finger millet

Good quality finger millet(*Eleusine coracana*) grains were selected. Finger millet is among minor cereal grains that are underutilised. It is a good source of bioactive compounds that include ferulic acid-rich arabinoxylans or feraxans, ferulic acid, caffeic acid, and quercetin have been

associated with certain health promoting properties and have been found bio accessible in the grain (Okwudili, U.H., *et al.*, 2017)

Finger millet was collected from the local stores of Townhall, Coimbatore.

5.Sorghum

Good quality sorghum grains were selected sorghum millet (*Sorghum bicolor*) is increasingly utilized for human consumption, due to the gluten-free nature and potential phenolic-induced health benefits. Sorghum grain is rich in bioactive phenolic compounds, such as ferulic acid are known to provide many health benefits, including antioxidant, anti-inflammatory, anti-proliferative, anti-diabetic, and anti-atherogenic activities.(Xu *et al.*,2021)

Sorghum was collected from the local stores of Townhall, Coimbatore.

6.Roasted Groundnut

Good quality groundnuts were selected. Groundnut is an invaluable source of protein, calories, essential fatty acids, vitamins, and minerals for human nutrition. Groundnut is a rich source of dietary protein with ability to meet up to 46% of recommended daily allowance. It is also a rich source of minerals such as K, Na, Ca, Mn, Fe, and Zn .(Ojiewo *et al.*,2020)

Roasted Groundnuts was collected from the local stores of Townhall, Coimbatore.

7.White Sesame Seeds

Good quality white sesame seeds were selected which was clear, free from rancidity or other foreign matter. Sesame seeds is popularly known as the “Queen of Oilseeds” due to its high degree of resistance to oxidation and rancidity. Sesame seeds contain two unique substances, sesamin and sesamol. Both of these substances belong to a group of special beneficial fibers called lignans and have a cholesterol lowering effect in humans and prevent high blood pressure and increase vitamin E supplies in animals.(Pathak *et al.*,2014)

White sesame seeds was collected from the local stores of Townhall, Coimbatore.

8. Garden cress seeds

Good quality garden cress seeds were selected. The seeds are rich source of proteins, dietary fiber, omega-3 fatty acids, iron, other essential nutrients and phytochemicals. They are rich in ascorbic acid, arachidic acid, folic acid, linoleic fatty acids and beta-carotene. (Doke and Guha,2014) Garden cress seeds was collected from the local stores of Townhall, Coimbatore.

9. Jaggery

Good quality jaggery was selected which was golden yellow in colour having hard texture, crystalline structure, sweet taste and less moisture content. It is also used as an energy food having therapeutic advantage so it can be used for blood purification, regular functioning of liver and keeping blood healthy. (Hirpara *et al.*, 2020)

Jaggery was collected from the local stores of Townhall, Coimbatore.

10. Dark chocolate

Good quality dark chocolate was selected. Chocolate is well known for its fine flavor and interest in chocolate has grown, owing to its physiological and potential health effects, such as regulation of blood pressure, insulin levels, vascular functions, oxidation processes, prebiotic effects, glucose homeostasis, and lipid metabolism. (Montagna *et al.*, 2019).

Dark Chocolate was collected from the local stores of Townhall, Coimbatore.

B. Processing of the selected ingredients

Processing of barnyard and foxtail millet

Processing of millets generally reduce the antinutritional properties and increase the bioavailability of the food products. Traditional methods of processing like soaking, roasting, germination, fermentation gave a greater impact on nutritional value of the millet. Decortication and dehulling are the general treatment of processing technology applied for millet to increase its organoleptic qualities. (Subasshini, V. and Thilagavathi, S. 2020)

I. Malting of the millets [Foxtail and barnyard]

Foxtail millet and barnyard millet are cleaned manually by removing the entire husk, stone and other extraneous materials. The raw, clean grains were soaked in water in the ratio of 1:3 for 12 hours. The soaked grains were stirred periodically in order to remove the gases accumulated around the grains and the steeped water was changed after every 3 hours interval to prevent the growth of undesirable microbes.

Germination is one of the processes practiced in legumes and cereals to increase their palatability and nutritional value via the breakdown of antinutrients such as phytate and protease inhibitors (Bhuvaneshwari *et al.*, 2020). The soaked grains were germinated at 30 °C for 33 hours.

The sprouted foxtail and barnyard millet were shade dried for 36 hours. The weight of the millets before and after drying were noted. The malted millets were ground into flour and sieved to obtain the fine powder of the flour. The weight of the millet flours obtained were also noted. The foxtail millet and barnyard millet flours were stored in air tight containers. The phytochemical compounds and nutrients of the flours were analysed in the laboratory. The Figure 2 represents the flowchart for the preparation of germinated barnyard and foxtail millet flour:

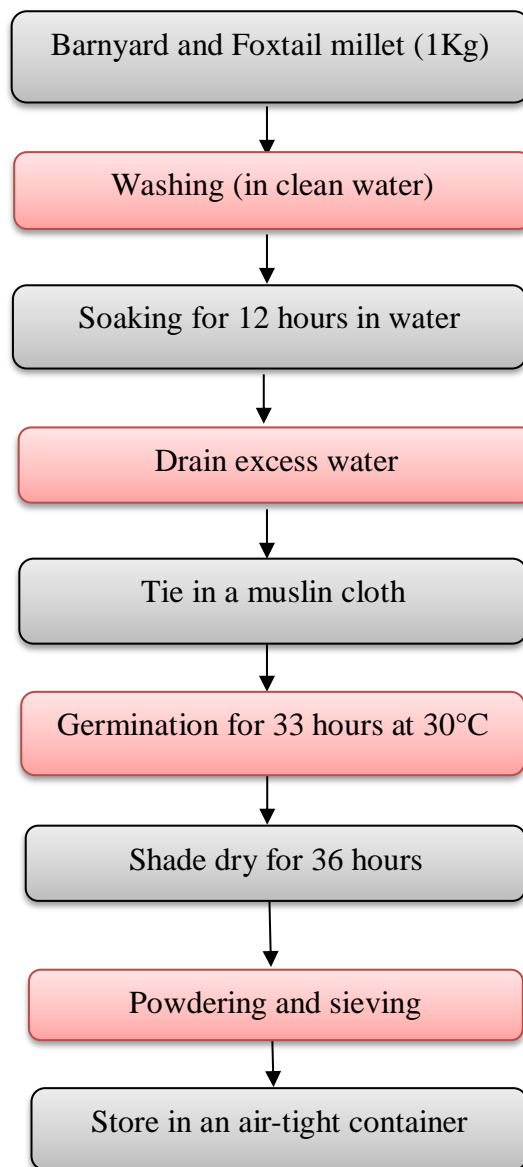


Figure 2: Flowchart for the preparation of germinated barnyard and foxtail millet flour

Processing of pearl millet, finger millet and sorghum

I. Popping of the millets [Pearl millet, Finger millet and Sorghum]

The grains (Pearl millet, Finger millet and sorghum) were cleaned to remove the dust, dirt and stones by winnowing and sieving. Grains were soaked in water for 2 hours and dried for 10 minutes to remove the surface moisture. The grains were popped by heating in an iron pan without the use of sand as heating means. The temperature was maintained at approximately 220°C with stirring constantly by wooden laddle. The grains began to pop after heating for 30 seconds. The grains after puffing were passed through a sieve to separate puffed and unpuffed grains. The popped grains were cooled and ground in a mixer into powdered form and stored in air tight container at room temperature for analysis. The Figure 3 represents the flowchart for the preparation of popped pearl millet, finger millet and sorghum millet flour:

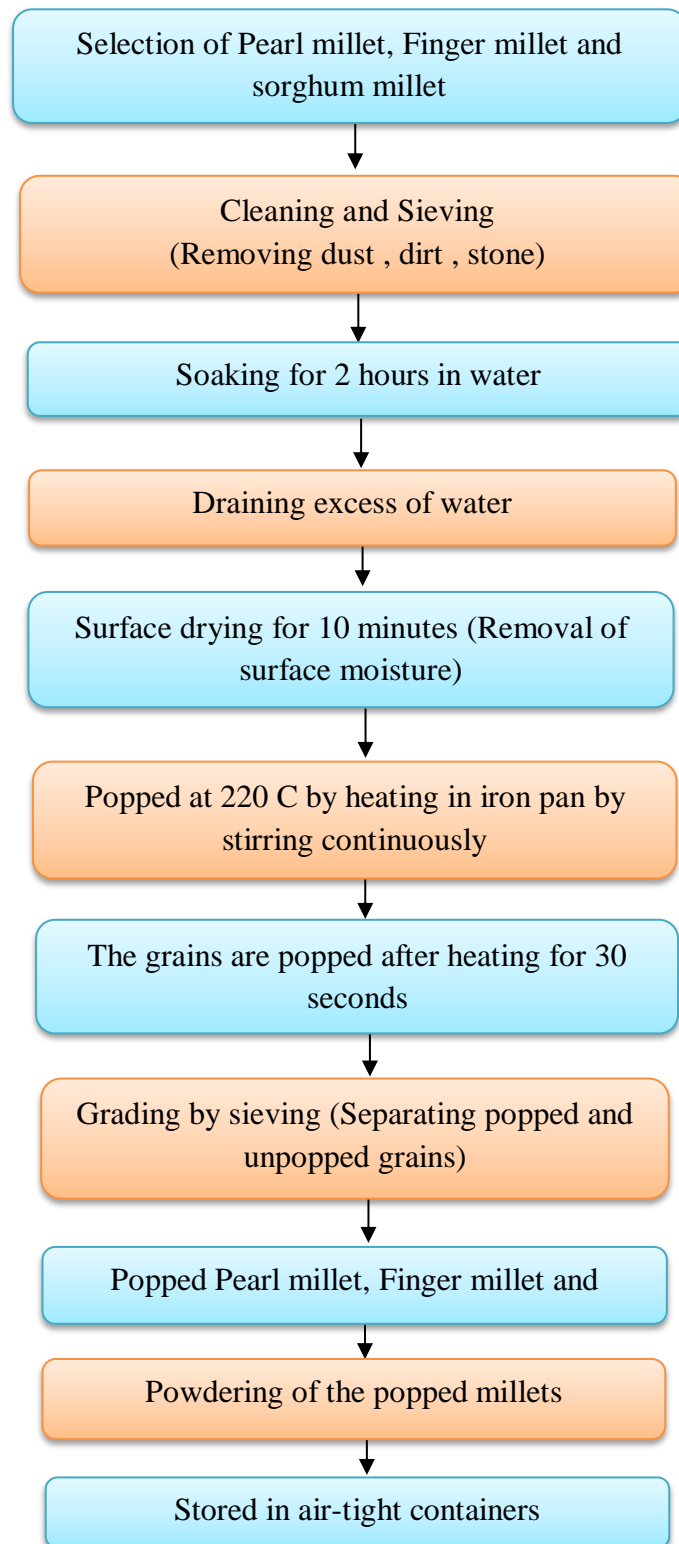


Figure 3: Flowchart for the preparation of popped pearl millet, finger millet and sorghum millet flour

The popping yield was determined as per the method given by Malleshi and Desikchar (1981)

$$\text{Popping yield (\%)} = \frac{\text{Weight of popped grain (g)}}{\text{Weight of popped grains x unpopped grains (g)}} \times 100$$

Roasting of white sesame seeds and garden cress seeds

Roasting is a common process applied for nuts, seeds and pulses to enhance flavor, desired colour and crunchy texture. In terms of nutrition, the roasting process enhances the carbohydrate and protein digestibility, β -glucan extractability, levels of dietary fiber, minerals, and antioxidants (Kora,2019).

White sesame seeds and garden cress seeds were roasted at an temperature of 200°C for 15 minutes till good aroma comes out.

Preparation Of Dark Chocolate Sauce

Dark chocolate bar was double boiled and melted. This was used as dark chocolate sauce.

C. Formulation and standardization of millet bars incorporating Oriental and Hannah sweet potato flour

According to the United States Department of Agriculture (USDA), a standardized recipe is defined as one that has been tried, adapted, and retried several times for use by a given food service operation and has been found to produce the same good results and yield every time when the exact procedures are used with same type of equipment and the same quantity and quality of ingredients. In easier terms, a standardized recipe is a complete, specific set of written instructions for cooks to produce consistent, high-quality recipes every time. Standardized recipes provide a means to establish consistency in the quality of all foods being made, menu planning, and food and labor costs. Understanding how to properly use standardized recipes ensures that the food being prepared is the same regardless of who does the cooking. The food should be the same in taste, texture, yield, appearance, nutritional value, and cost.

1. Sprouted barnyard and foxtail millet bars incorporating oriental and hannah sweet potato flour

Table I presents the composition of sprouted barnyard and foxtail millet bar incorporated with Oriental and Hannah sweet potato flour

TABLE I

Composition of sprouted barnyard and foxtail millet bar incorporated with Oriental and Hannah sweet potato flour

Ingredients	Standard	Variation I	Variation II	Variation III
Sprouted barnyard millet bars incorporated with Oriental and Hannah sweet potato flour				
Sweet potato flour (Both Oriental and Hannah variety) (g)	-	40	50	60
Jaggery(g)	100	100	100	100
Sprouted barnyard millet flour(g)	90	50	40	30
Peanuts(g)	5	5	5	5
Sesame seeds(g)	2	2	2	2
Dark chocolate(g)	3	3	3	3
Sprouted foxtail millet bars incorporated with Oriental and Hannah sweet potato flour				
Sweet potato flour (Both Oriental and Hannah variety) (g)	-	40	50	60
Jaggery(g)	100	100	100	100
Sprouted foxtail millet flour(g)	90	50	40	30
Peanuts(g)	5	5	5	5
Garden cress seeds(g)	2	2	2	2
Dark chocolate(g)	3	3	3	3

The product was standardised by following the standard procedure used for the preparation of sweet potato bars. The variations were prepared with 10%, 20% and 30% incorporation of sprouted barnyard and sprouted foxtail millet flour in the Oriental and Hannah sweet potato bars.

For the preparation of sprouted barnyard millet sweet potato bar, all the pre- processed ingredients (sweet potato flour, germinated barnyard millet flour, roasted sesame seeds and coarsely powdered roasted groundnuts) were mixed well and kept aside.

For the preparation of sprouted foxtail millet sweet potato bar, all the pre- processed ingredients (sweet potato flour, germinated foxtail millet flour, roasted garden cress seeds and coarsely powdered roasted groundnuts) were mixed well and kept aside.

In a thick bottomed vessel, jaggery and water are added in the ratio of 2:1 and once the jaggery melts, the jaggery syrup is strained to remove the unwanted substances and it is again allowed to boil

until it reaches the hard ball stage. Once the hard ball stage is reached, the vessel is taken off from the flame and all the pre- processed ingredients are added in the jaggery syrup and mixed well. In a flat surface, ghee is applied on a butter paper and the mixture is poured and rolled evenly and cut in the shape of rectangular bars using a stainless-steel knife. After the bars are cooled, it is dipped inside the double boiled dark chocolate sauce.

2.Popped finger millet, pearl millet and sorghum millet bars incorporating oriental and hannah sweet potato flour

Table II presents composition of popped finger millet, pearl millet and sorghum millet bars incorporated with Oriental and Hannah sweet potato flour

TABLE II

Composition of popped finger millet, pearl millet and sorghum millet bars incorporated with Oriental and Hannah sweet potato flour

Ingredients	Standard	Variation I	Variation II	Variation III
Popped finger millet bars incorporated with Oriental and Hannah sweet potato flour				
Sweet potato flour (Both Oriental and Hannah variety)	-	40	50	60
Jaggery(g)	100	100	100	100
Popped finger millet flour(g)	90	50	40	30
Peanuts(g)	5	5	5	5
Sesame seeds(g)	2	2	2	2
Dark chocolate (g)	3	3	3	3
Popped pearl millet bars incorporated with Oriental and Hannah sweet potato flour				
Sweet potato flour (Both Oriental and Hannah variety) (g)	-	40	50	60
Jaggery(g)	100	100	100	100
Popped pearl millet flour(g)	90	50	40	30
Peanuts(g)	5	5	5	5
Sesame seeds(g)	2	2	2	2
Dark chocolate(g)	3	3	3	3
Popped sorghum millet bars incorporated with Oriental and Hannah sweet potato flour				
Sweet potato flour (Both Oriental and Hannah variety)	-	40	50	60
Jaggery(g)	100	100	100	100
Popped sorghum millet flour(g)	90	50	40	30
Peanuts(g)	5	5	5	5
Sesame seeds(g)	2	2	2	2
Dark chocolate(g)	3	3	3	3

The products were standardised by following the standard procedure used for the preparation of sweet potato bars. The variations were prepared with 10%, 20% and 30% incorporation of popped pearl millet flour, finger millet and sorghum flour in the Oriental and Hannah sweet potato bars. The other ingredient such as sesame seeds and roasted groundnut were kept constant.

For the preparation of popped pearl millet sweet potato bar, all the pre- processed ingredients (sweet potato flour, popped pearl millet flour, roasted sesame seeds and coarsely powdered roasted groundnuts) were mixed well and kept aside.

For the preparation of popped finger millet sweet potato bar, all the pre- processed ingredients (sweet potato flour, popped finger millet flour, roasted sesame seeds and coarsely powdered roasted groundnuts) were mixed well and kept aside.

For the preparation of popped sorghum millet sweet potato bar, all the pre- processed ingredients (sweet potato flour, popped sorghum millet flour, roasted sesame seeds and coarsely powdered roasted groundnuts) were mixed well and kept aside.

In a thick bottomed vessel, jaggery and water are added in the ratio of 2:1 and once the jaggery melts, the jaggery syrup is strained to remove the unwanted substances and it is again allowed to boil until it reaches the hard ball stage. Once the hard ball stage is reached, the vessel is taken off from the flame and all the pre- processed ingredients are added in the jaggery syrup and mixed well. In a flat surface, ghee is applied on a butter paper and the mixture is poured and rolled evenly and cut in the shape of rectangular bars using a stainless-steel knife. After the bars are cooled, it is dipped inside the double boiled dark chocolate sauce.

D. Organoleptic evaluation of the developed products:

Sensory evaluation can be defined as the quality of product which is assessed by means of human sensory organs. Sensory analysis is an important tool in new product development to evaluate the quality and the commercial acceptance of new foods. Panel members form an important tool of sensory analysis. (Mihafu *et al.*,2020) The developed products were organoleptically evaluated by 30 semi- trained panel members in the Food Sensory Laboratory at Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore. Bar samples were presented on odourless white ceramic plates at ambient temperature. Drinking water were provided for cleansing between samples. Panelists were instructed to use the drinking water to cleanse their palates before tasting the samples and at any time during the test as needed. The sensory characteristics of the developed products like Appearance, Taste, Colour, Texture, Flavour and Overall acceptability were assessed using the 9- point Hedonic Scale where 9=like extremely - 8=like very much , 7=like moderately ,6=like slightly , 5=neither like nor dislike ,4= dislike slightly ,3=dislike moderately ,2= dislike very much,1= dislike extremely. Using the SPSS software, the data obtained were statistically analyzed

by One Way ANOVA, Post hoc and DMRT which is used to determine statistical significant difference between the samples.



ORGANOLEPTIC EVALUATION OF ORIENTAL AND HANNAH SWEET POTATO FLOUR INCORPORATED MILLET BARS

PLATE II

Phase IV: Nutrient Analysis of the Oriental sweet potato flour bars incorporated bars

A. Analysing the nutrients present in Oriental sweet potato flour bars incorporated bars

Two varieties of sweet potato flours (Oriental and Hannah) were analysed for all the nutrients. After the analysis, the Oriental sweet potato flour that had high beta carotene level and hence the Oriental sweet potato flour incorporated bars were analysed for the nutrient in the laboratory.

The moisture, ash, energy, carbohydrate, protein, fat, fibre, calcium, iron , vitamin C , beta carotene were analyzed in the Oriental sweet potato flour incorporated millet bars following the standard procedure discussed in the phase II.

PHASE V: Microbial analysis, Color analysis, Texture characteristics and shelf - life testing of all the products developed out of Oriental and Hannah variety of sweet potato flour

A. Analysing the microbial content, colour, texture characteristics and shelf life of all the developed out of Oriental and Hannah variety of sweet potato flour

i. Microbial Analysis

Microbial load was assessed by pour plate method. Ten grams of each sample was mixed in 90 ml sterile water blank to give 10^{-1} dilution. Subsequent dilutions up to 10^{-7} were made by transferring serially 1 ml of the dilution to 9 ml of sterile water blanks. The bacterial populations were estimated by transferring 1 ml of 10^{-2} , 10^{-3} , 10^{-4} , 10^{-5} , 10^{-6} , 10^{-7} dilutions respectively to a sterile petri dish and approximately 20 ml of nutrient agar media were poured into plates. The plates were rotated twice in clockwise and anticlockwise direction for uniform distribution of the inoculums. After solidification of the media, plates were kept for incubation in an inverted position at $30 \pm 1^\circ \text{C}$ for two days and emerged colonies were counted.

ii. Colour

Color measurements were conducted using C-10 portable colorimeter which is a colour difference meter tester. The products were tested after 1 day of preparation of products. The instrument that was used to measure the colour was based on $L^*a^*b^*$ colour system, where ΔL^+ (lightness), Δa^+ (redness) and Δb^+ (yellowness). Before testing the sample, the instrument was calibrated by using a black and white calibration cavity which was provided with instrument. The instrument was placed on the energy bar formulation and the values of ΔL^* (lightness), Δa^* (redness) and Δb^* (yellowness) for each energy bar was recorded and tabulated.

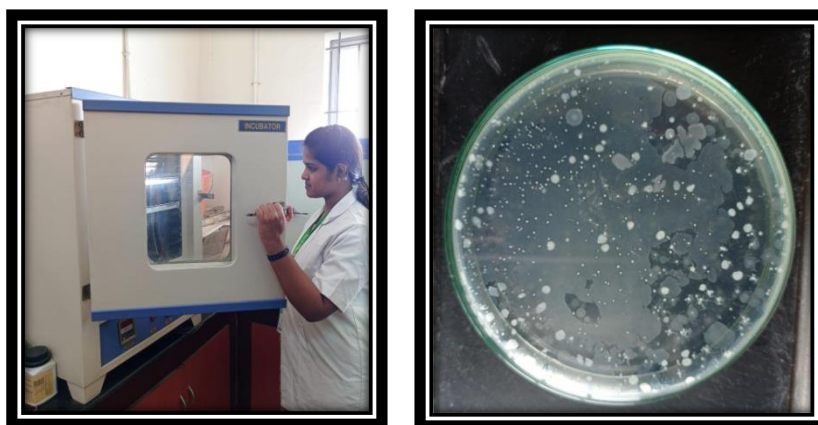
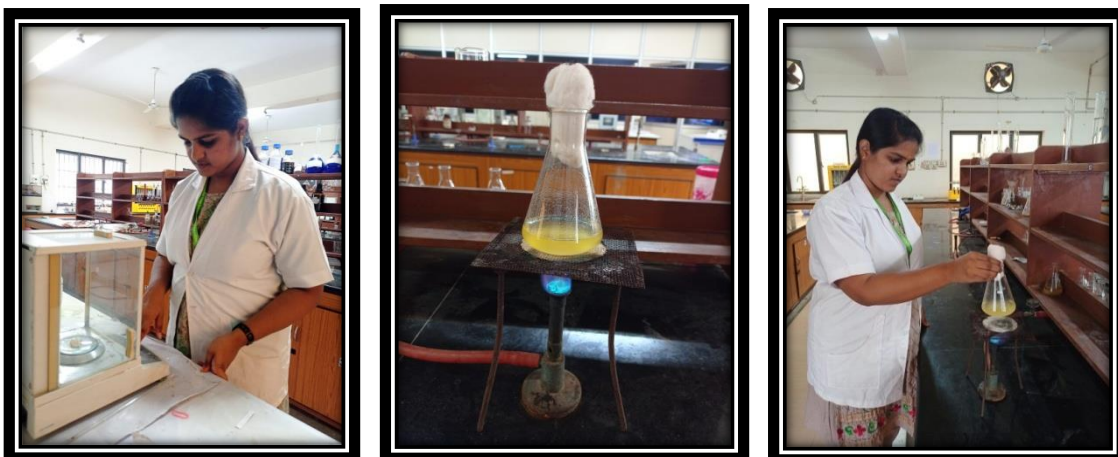
iii. Texture Analysis

Textural characteristics of the developed sweet potato millet bars were determined according to a three - point bending test using texture profile analyser (Model: EZ – XS, Shimadzu Corporation, Japan). The three-point bending test makes it possible to evaluate the hardness and adhesiveness of the samples by performing a bending test. The measurement was carried out with a test speed of 1mm/sec. The sample was placed centrally under the three-point bending rig probe until the probe came in contact with the sample. The peak force was recorded as the hardness value of the bars.

iv. Shelf-life analysis by accelerated shelf life study

Oriental and Hannah sweet potato millet bars were used for packaging and storage. LDPE laminated stand up paper pouches was selected for storage studies. Accelerated storage study was carried out where one set of packets were stored in an incubator (45°C) and the other set was stored at ambient temperature for 30 days. After every 5 days interval, samples were drawn for moisture

analysis. During storage care was taken to keep samples free from pest attack. Samples were randomly collected for analysis during the storage period.



DETERMINATION OF TOTAL PLATE COUNT OF THE ORIENTAL AND HANNAH SWEET POTATO FLOUR INCORPORATED MILLER BARS

PLATE III



COLOUR ANALYSIS OF THE ORIENTAL AND HANNAH SWEET POTATO FLOUR INCORPORATED MILLER BARS

PLATE IV

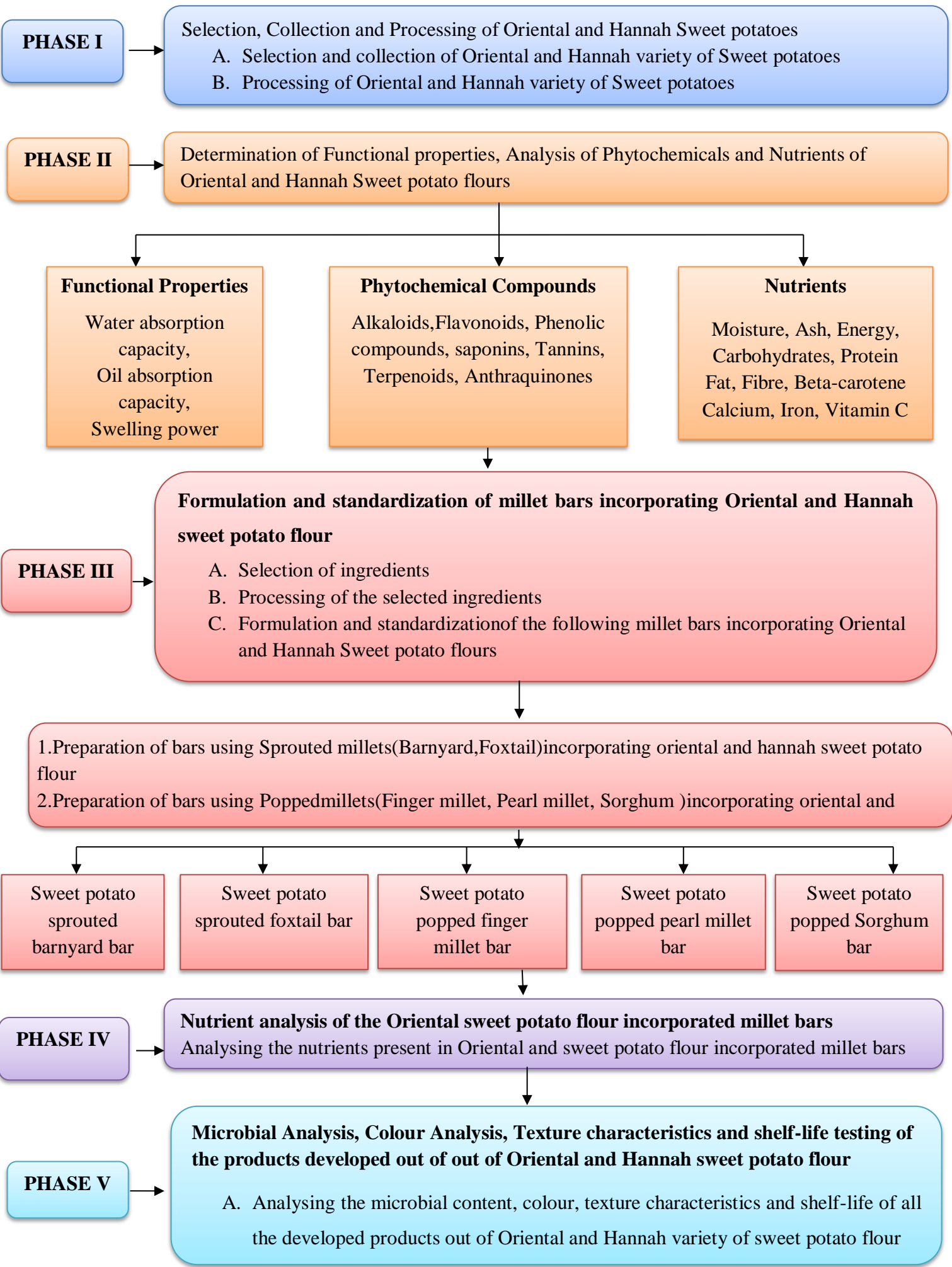


Figure 4

RESEARCH DESIGN

Result and Discussion

IV. RESULTS AND DISCUSSION

The results and discussion of the study “Formulation of Beta carotene and Fibre Rich Nutritious Bar Using Sweet Potato (*Ipomoea batatas*) and Millets” is presented under the following headings.

PHASE I: Selection and collection of Oriental and Hannah variety of sweet potato

A. Selection, drying and powdering of the Oriental and Hannah sweet potato flour

PHASE II: Determination of functional properties, analysis of phytochemicals and nutrients of the oriental and hannah variety of sweet potato flour

- A. Determination of functional properties of Oriental and Hannah varieties of sweet potato flour
- B. Analysing the Phytochemical compounds present in Oriental and Hannah varieties of sweet potato flour
- C. Analysing the nutrients present in Oriental and Hannah varieties of sweet potato flour

PHASE III: Formulation and Standardization of the millet bars incorporating Oriental and Hannah Sweet potato flours

- A. Processing of the selected ingredients
- B. Organoleptic evaluation of the developed products

PHASE IV: Nutrient Analysis of the Oriental sweet potato flour bars incorporated millet bars

- A. Nutrient Analysis of the most acceptable Oriental sweet potato flour incorporated millet bars

PHASE V: Microbial analysis, Color analysis, Texture characteristics and shelf - life testing of the Oriental and Hannah sweet potato millet bars

- A. Microbial analysis, Color analysis, Texture characteristics and shelf - life testing of the Oriental and Hannah sweet potato millet bars

PHASE I: Selection and collection of Oriental and Hannah variety of sweet potato

A. Selecting, drying and powdering of the Oriental and Hannah sweet potato flour

Sweet potato was selected based on the local availability and the amount of research previously done on them. Hundred grams of the Oriental and Hannah sweet potato flours were taken and it was dried. They were dried in the cabinet drier for 45°C for 6 hours. The dried sweet potatoes were powdered in a pulverizer until the desired fineness was reached. To obtain fine powder it was sieved in a 1.5mm wire mesh. Then the powders were transferred into well cleaned and dried air-tight containers.

Hundred gram of fresh sample of the Oriental and Hannah sweet potatoes were taken and after drying 42g and 40g of Oriental sweet potatoes and Hannah sweet potatoes were obtained respectively. The sweet potato flour obtained from Oriental and Hannah sweet potatoes were 40g and 38 g respectively. After sieving the weight of the Oriental and Hannah sweet potatoes were 38g and 36g respectively. A supported study by Trang *et al.* (2020) revealed that sweet potatoes contain 62.7% moisture.

PHASE II: Determination of functional properties, analysis of phytochemicals and nutrients of the oriental and hannah variety of sweet potato flour

A. Determination of functional properties of Oriental and Hannah varieties of sweet potato flour

Functional properties of Oriental and Hannah varieties of sweet potato flour are shown in Table III

TABLE III

Functional properties of Oriental and Hannah varieties of sweet potato flour

Functional properties	Mean ± SD	
	Oriental sweet potato flour	Hannah sweet potato flour
Water absorption capacity(g/100g)	295±0.07	250±0.03
Oil absorption capacity(g/100g)	110±0.10	95±0.05
Swelling power(g/g)	3.45±0.01	3.35±0.03

Table III revealed that the water absorption capacity of Oriental sweet potato flour and Hannah sweet potato flour is 295g and 250g respectively. Findings of a study carried out by Olubunmi *et al.*2017 reported that the water absorption capacity ranged from 212.0 to 370.5% for native and steamed sweet potato flour. The Oil absorption capacity of Oriental and Hannah sweet potato flour was 110±0.10 and 95±0.05 respectively. Findings of a study carried out by Azima *et al.*,2020 reported that the oil absorption capacity of yellow sweet potato and white sweet potato was 1.152g/g and 1.150g/g respectively. The swelling power of Oriental and Hannah sweet potato flour was 3.45g/g and 3.35g/g respectively. Findings of a study carried out by Kusumayanti *et al.*(2015) reported that the swelling power of white sweet potato and yellow sweet potato flour was 3.40g/g and 3.67 g/g respectively.

B. Analysing the Phytochemical compounds present in Oriental and Hannah varieties of sweet potato flour

Phytochemicals are compounds that are produced by plants ("phyto" means "plant"). They are found in fruits, vegetables, grains, beans, and other plants. Some of these phytochemicals are believed to protect cells from damage that could lead to disease. (Mahajan *et al.*, 2012)

The qualitative analysis of phytochemical profile in Oriental and Hannah sweet potato flour extracts are presented in the Table IV. For the ethanolic extracts, oriental and hannah sweet potato flour was taken

and 30 ml of ethanol was added and shaken vigorously for 5-10 minutes and left for 24hr after which the extract is filtered using Whatman filter paper No. 4.

Table IV gives the details on the phytochemical compounds present in oriental and hannah sweet potato flour.

TABLE IV
Phytochemical profile of Oriental and Hannah sweet potato flour

Phytochemicals	Oriental sweet potato flour	Hannah sweet potato flour
Alkaloids	++	++
Flavonoids	+++	+++
Saponins	+++	+++
Tannins	++	-
Terpenoids	+++	++
Anthraquinones	-	-
Phenolic compounds	++	++

(+++)-**Highly Present** (++)-**Moderately Present**

(+)-**Presence** (-)-**Absence**

The Presence of alkaloid in the sample was identified using the picric acid test. It was moderately present in the Oriental and Hannah sweet potato flour.

Conc.H₂SO₄ test was used to determine flavonoid in the sample. An orange colour indicated the presence of flavonoids. Flavonoid is highly present in Oriental and Hannah sweet potato flours.

The Presence of saponin in the sample was identified using foam test. In both Oriental and Hannah sweet potato flour, more foam was formed which indicated the high presence of saponin in both the flours.

The presence of Tannins in the Oriental and Hannah sweet potato flour was identified by Ferric Chloride reagent test. Oriental sweet potato had moderate tannin content, whereas the tannin content was absent in Hannah sweet potato flour.

The Presence of Terpenoids in the sample was identified using Salkowkis test. Terpenoids are highly present in Oriental sweet potato flour. In hannah sweet potato flour the terpenoids were moderately present.

The Anthraquinone in the sample was identified using Borntranger's test, it was absent in both Oriental and Hannah sweet potato flour.

Lead acetate test was used to determine the presence of phenolic compounds in the sample. White precipitate was formed in both Oriental and Hannah sweet potato flours which indicated the presence of phenolic compounds in both flours.

C. Analysing the nutrients present in Oriental and Hannah varieties of sweet potato flour

Nutrient analysis refers to the process of determining the nutritional content of foods and food products. The nutrients of Oriental and Hannah sweet potato flour were analysed using the AOAC (The Association of Official Analytical Chemists) methods. The Oriental and Hannah sweet potato flours were ashed and diluted for the estimation of calcium, iron and vitamin C.

Nutrients present in Oriental and Hannah sweet potato flour are shown in Table V

TABLE V
Nutrient Content of Oriental and Hannah sweet potato flour

Nutrients	Mean \pm SD	
	Oriental Sweet Potato Flour	Hannah Sweet Potato Flour
Moisture (%)	6.7 \pm 0.08	6.3 \pm 0.11
Ash(g)	1.4 \pm 0.01	1.3 \pm 0.01
Energy (Kcal)	381.5 \pm 0.5	365.3 \pm 0.57
Carbohydrate(g)	86.6 \pm 0.36	85.0 \pm 1.00
Protein(g)	4.7 \pm 0.25	3.6 \pm 0.15
Fat(g)	4.4 \pm 0.05	4.2 \pm 0.36
Dietary fibre (g)	4.4 \pm 0.28	3.5 \pm 0.32
Calcium (mg)	8.7 \pm 0.28	6.0 \pm 0.05
Iron (mg)	8.8 \pm 0.40	7.2 \pm 0.15
Vitamin C (mg)	2.7 \pm 0.26	2.2 \pm 0.10
Beta – carotene (μ g)	350	60

Moisture content of Oriental sweet potato flour was higher with 6.7% when compared with Hannah sweet potato with 6.3%. The moisture content values obtained were lower than the recommended moisture content (10%) for storage stability (Iwe *et al.*2017) thus, the sweet potato flour will have a longer shelf life if properly stored under a good condition.

Ash content of Oriental sweet potato flour was higher with 1.4g while Hannah sweet potato flour had 1.3g. The obtained values were supported by the study of Nogueira *et al.* (2018) that yellow fleshed sweet potato had ash value of 1.64%.

Energy value of Oriental sweet potato flour was higher with 381.5Kcal while Hannah sweet potato flour had 365.3Kcal. In a study by Arshad *et al.* (2021), the energy value of white fleshed sweet potato was 362.73Kcal/100g.

Analysis of macronutrients like carbohydrate revealed that Oriental sweet potato flour was rich in carbohydrate with 86.6g and hannah sweet potato flour had 85.0g. The high carbohydrate content observed implies that sweet potato was a rich source of carbohydrate.

Protein content of Oriental sweet potato flour was higher with 4.7g while Hannah sweet potato flour had 3.6g. It was supported by the study of Dako *et al.* (2016) that sweet potato has low protein values that ranged from 2.48 to 6.50g/100g.

Analysis of fat revealed that Oriental sweet potato flour was rich in fat with 4.4g while Oriental sweet potato flour had 4.2g. A study by Waidyarathna & Ekanayake. (2021) revealed that the fat content of white fleshed sweet potato was 4.2g/100g.

Fibre content of Oriental sweet potato flour was higher with 4.4g while Hannah sweet potato flour had 3.5g. A study by Rayamajhi and Mishra. (2020) have indicated that the fibre content of white – fleshed sweet potato was found to be 3.54g/100g.

With regard to micronutrients, the calcium content was 8.7mg in Oriental sweet potato flour and calcium was low in Hannah sweet potato flour with 6.0mg.

With regard to iron Oriental sweet potato flour had higher quantity of iron with 8.8mg and iron was low in Hannah sweet potato flour with 7.2mg. The results obtained in the study are similar to the report of Oloniyo *et al.* (2021) that the iron content of sweet potatoes ranged from 8.8mg/100g.

Vitamin-C content of Oriental sweet potato flour was higher with 2.7mg while Hannah sweet potato flour had low vitamin-C content with 2.2mg. In a study by Kamal *et al.* (2014) , the vitamin C content in sweet potato was 2.45mg/100g.

Beta - carotene content of Oriental sweet potato flour was higher with 350mcg while Hannah sweet potato flour had low beta- carotene content of 60mcg. The beta-carotene values were correlated with the intensity of sweet potato flesh colour.

From Table V, it was inferred that the nutrients and beta carotene present in the oriental sweet potato flour was higher when compared to hannah sweet potato flour. Therefore, the nutrient content of the Oriental sweet potato flour incorporated millet bars were analysed in the laboratory. Figure 5 represents the comparison of nutrients present in oriental and Hannah sweet potato flour

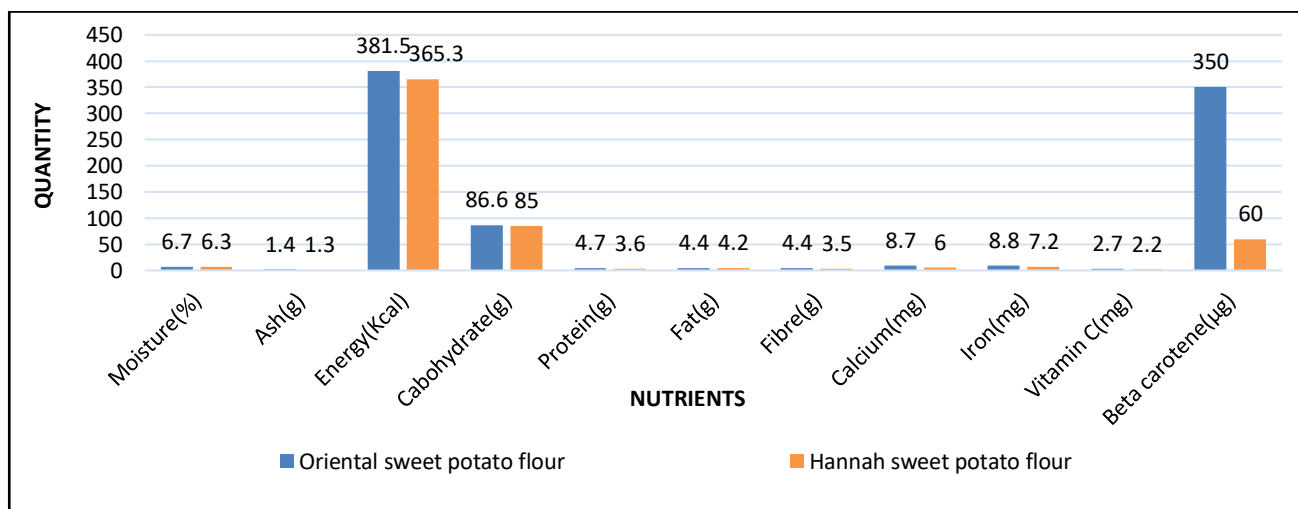


Figure 5: Comparison of nutrients present in oriental and Hannah sweet potato flour

Phase III: Formulation and standardization of the millet bars incorporating oriental and Hannah sweet potato flours

A. Processing of the selected ingredients

i. Malting of millets (Barnyard and Foxtail)

100g of barnyard millet and foxtail millet were taken. It was cleaned, soaked, sprouted, dried and powdered. The weight of the product before and after processing was noted. Hundred grams of fresh sample of the barnyard and foxtail millet were taken and after sprouting and drying 95g and 97g of barnyard millet and foxtail millet were obtained respectively. The barnyard millet flour and foxtail millet flour obtained were 93g and 95 g respectively. After sieving the weight of the barnyard millet flour and foxtail millet flour were 90g. The flour obtained from 100 g of the barnyard and foxtail millet were 90% of the original weight.

ii. Popping of millets (finger millet, pearl millet and sorghum)

100g of finger millet, pearl millet and sorghum were taken. It was cleaned, soaked, dried and popped. Hundred grams of finger millet, pearl millet and sorghum millet were taken and the popping yield of finger millet, pearl millet and sorghum millet were 80%, 60% and 40% respectively.

B. Organoleptic evaluation of the developed products

Sensory evaluation was carried out to evaluate the products by panel of members towards the satisfactory- using a 9-point Hedonic rating scale. Oriental and Hannah varieties of sweet potato bars were prepared with the incorporation of Millet flours (Barnyard, foxtail, pearl millet finger millet and sorghum). Standard and Variation of the products were evaluated based on the 9-point Hedonic rating Scale for Sensory attributes like Appearance, Colour, Flavour, Taste, Texture and Overall acceptability by 30 members for Successive trials.

a. Sprouted barnyard millet bar incorporated with Oriental sweet potato flour

The Table VI presents the mean acceptability score of sprouted barnyard millet bar incorporated with Oriental sweet potato flour.

TABLE VI
Mean acceptability sensory scores of sprouted barnyard millet bar incorporated with Oriental sweet potato flour

Sensory Characteristics	Mean \pm S.D of Sensory score				One-Way ANOVA (F value)	One way ANOVA (P value)
	Standard	Variation I	Variation II	Variation III		
Appearance	8.73 \pm 0.449	7.16 \pm 0.530	8.13 \pm 0.507	8.90 \pm 0.305	88.305	<.001*
Colour	8.73 \pm 0.449	7.16 \pm 0.530	8.13 \pm 0.434	8.66 \pm 0.479	69.686	<.001*
Flavour	8.86 \pm 0.345	6.93 \pm 0.365	8.06 \pm 0.520	8.73 \pm 0.44	128.909	<.001*
Taste	8.83 \pm 0.379	7.00 \pm 0.454	8.10 \pm 0.402	8.86 \pm 0.345	145.246	<.001*
Texture	8.70 \pm 0.466	7.03 \pm 0.319	8.23 \pm 0.430	8.76 \pm 0.430	112.069	<.001*
Overall acceptability	8.90 \pm 0.205	6.96 \pm 0.319	8.06 \pm 0.365	8.93 \pm 0.353	261.057	<.001*

M \pm S.D -Mean \pm Standard Deviation; * - Significant at 5% level

S-Standard barnyard millet bar**Variation I-40% incorporation of sweet potato flour in standard barnyard millet bar****Variation II-50% incorporation of sweet potato flour in standard barnyard millet bar****Variation III-60% incorporation of sweet potato flour in standard barnyard millet bar**

With regard to appearance, variation 3 scored highest score of 8.9 ± 0.3 followed by standard, variation II and variation I with scores of 8.7 ± 0.4 , 8.1 ± 0.5 and 7.1 ± 0.5 respectively. With regard to colour standard obtained the highest score of 8.7 ± 0.4 followed by variation III, Variation II and variation I with a score of 8.6 ± 0.4 , 8.1 ± 0.4 and 7.1 ± 0.5 respectively. Standard scored the highest score of 8.8 ± 0.3 for flavour followed by variation III, variation II and variation I with scores of 8.7 ± 0.4 , 8.0 ± 0.5 and 6.9 ± 0.3 respectively. With regard to taste, standard and variation III scored the highest score of 8.8 ± 0.3 followed by variation II and variation I with a score of 8.1 ± 0.4 and 7.0 ± 0.4 respectively. For texture, the mean acceptability scores of standard and variation III scored highest score of 8.7 ± 0.4 followed by variation II and variation I with score of 8.2 ± 0.4 and 7.0 ± 0.3 respectively. With regard to overall acceptability of sweet potato sprouted barnyard millet bar, variation III scored the highest scores of 8.9 ± 0.3 followed by standard, variation II and variation I with score of 8.9 ± 0.2 , 8.0 ± 0.3 , 6.9 ± 0.3 respectively.

By performing the one-way ANOVA test, it was shown that there is a significant difference between the standard bar and variation I, II and III. The difference is between the organoleptic characteristics like appearance, colour, flavor, taste, texture and overall acceptability ($p < 0.05$).

b. Sprouted foxtail millet bar incorporated with Oriental sweet potato flour

The Table VII presents the mean acceptability score of sprouted foxtail millet bar incorporated with Oriental sweet potato flour

TABLE VII
Mean acceptability sensory scores of sprouted foxtail millet bar incorporated with Oriental sweet potato flour

Sensory Characteristics	M ± S.D of Sensory score				One-Way ANOVA (F value)	One way ANOVA (P value)
	Standard	Variation I	Variation II	Variation III		
Appearance	8.83 ± 0.379	6.90 ± 0.402	8.80 ± 0.406	8.23 ± 0.504	135.226	<.001*
Colour	8.76 ± 0.430	7.10 ± 0.547	8.80 ± 0.406	8.26 ± 0.520	82.058	<.001*
Flavour	8.83 ± 0.379	7.03 ± 0.413	8.76 ± 0.430	8.23 ± 0.504	110.518	<.001*
Taste	8.90 ± 0.305	6.93 ± 0.583	8.93 ± 0.253	7.96 ± 0.490	145.572	<.001*
Texture	8.80 ± 0.406	6.93 ± 0.520	8.76 ± 0.430	8.06 ± 0.520	102.551	<.001*
Overall acceptability	8.93 ± 0.253	6.93 ± 0.449	8.90 ± 0.305	8.00 ± 0.371	214.743	<.001*

M±S.D -Mean ± Standard Deviation; * - Significant at 5% level

S-Standard sweet potato bar**Variation I-40% incorporation of sweet potato flour in standard foxtail millet bar****Variation II-50% incorporation of sweet potato flour in standard foxtail millet bar**

Variation III-60% incorporation of sweet potato flour in standard foxtail millet bar

With regard to appearance, variation 2 and standard obtained the highest score of 8.8 ± 0.4 followed by standard, variation III and variation I with scores of 8.8 ± 0.3 , 8.2 ± 0.5 and 6.9 ± 0.4 respectively. Variation II scored the highest score of 8.8 ± 0.4 for colour followed by standard, variation III, variation I with scores of 8.7 ± 0.4 , 8.2 ± 0.5 and 7.1 ± 0.5 respectively. With regard to flavour standard obtained the highest score of 8.8 ± 0.3 followed by variation II, variation III and variation I with a score of 8.7 ± 0.4 , 8.2 ± 0.5 and 7.0 ± 0.4 respectively. Standard scored the highest score of 8.9 ± 0.3 for taste followed by variation II, variation III and variation I with scores of 8.9 ± 0.2 , 7.9 ± 0.4 and 6.9 ± 0.5 respectively. For texture, the mean acceptability scores of standard scored highest score of 8.7 ± 0.4 followed by variation II and variation III and variation I with score of 8.7 ± 0.4 , 8.0 ± 0.5 and 6.93 ± 0.5 respectively. With regard to overall acceptability of sweet potato sprouted foxtail millet bar, the variation II scored the highest score of 8.9 ± 0.3 followed by standard, variation III and variation I with score of 8.9 ± 0.2 , 8.0 ± 0.3 and 6.9 ± 0.4 respectively. A study by Mithila *et al.* (2021) revealed that from the sensory attributes of the multi-millet (foxtail, sorghum, bajra) noodles incorporated with sweet potato flour, it may be concluded that good quality multi-millet noodles can be processed the incorporation of sweet potato flour and the developed product was more acceptable.

By performing the one-way ANOVA test, it was shown that there is a significant difference between the standard bar and variation I, II and III. The difference is between the organoleptic characteristics like appearance, colour, flavor, taste, texture and overall acceptability ($p < 0.05$).

c. Popped finger millet bar incorporated with Oriental sweet potato flour

The Table VIII presents the mean acceptability score of popped finger millet bar incorporated with Oriental sweet potato flour

TABLE VIII
Mean acceptability sensory scores of popped finger millet bar incorporated with Oriental sweet potato flour

Sensory Characteristics	M \pm S.D of Sensory score				One-Way ANOVA (F value)	One way ANOVA (P value)
	Standard	Variation I	Variation II	Variation III		
Appearance	8.90 ± 0.305	8.90 ± 0.305	7.13 ± 0.434	8.13 ± 0.345	170.313	<.001*
Colour	8.76 ± 0.430	8.80 ± 0.406	7.23 ± 0.568	8.30 ± 0.466	71.982	<.001*
Flavour	8.83 ± 0.379	8.83 ± 0.379	7.13 ± 0.571	8.30 ± 0.534	85.667	<.001*
Taste	8.70 ± 0.305	8.96 ± 0.430	7.06 ± 0.449	8.10 ± 0.480	118.358	<.001*
Texture	8.80 ± 0.406	8.86 ± 0.345	7.10 ± 0.480	8.20 ± 0.484	106.985	<.001*
Overall acceptability	8.80 ± 0.305	8.90 ± 0.305	7.03 ± 0.413	8.16 ± 0.530	145.974	<.001*

M \pm S.D -Mean \pm Standard Deviation; * - Significant at 5% level

S-Standard finger millet bar

Variation I-40% incorporation of sweet potato flour in standard finger millet bar

Variation II-50% incorporation of sweet potato flour in standard finger millet bar
Variation III-60% incorporation of sweet potato flour in standard finger millet bar

With regard to appearance, standard and variation I obtained the highest score of 8.9 ± 0.3 respectively followed by variation III and variation II with scores of 8.1 ± 0.3 and 7.1 ± 0.4 respectively. Variation I scored the highest score of 8.8 ± 0.4 for colour followed by standard, variation III and variation II with scores of 8.7 ± 0.4 , 8.3 ± 0.4 and 7.2 ± 0.5 respectively. With regard to flavour standard and variation I obtained the highest score of 8.8 ± 0.3 and 8.8 ± 0.5 followed by variation III and variation II with a score of 8.3 ± 7.1 and 7.1 ± 0.5 respectively. Variation I scored the highest score of 8.9 ± 0.4 for taste followed by standard, variation 3 and variation II with scores of 8.7 ± 0.4 , 8.1 ± 0.4 and 7.0 ± 0.4 respectively. For texture, the mean acceptability scores of standard scored highest score of 8.8 ± 0.4 followed by standard, variation III and variation II with score of 8.8 ± 0.3 , 8.2 ± 0.4 and 7.1 ± 0.4 respectively. With regard to overall acceptability of sweet potato popped finger millet bar, the variation I scored the highest score of 8.9 ± 0.3 followed by standard, variation III and variation II with score of 8.8 ± 0.3 , 8.1 ± 0.5 and 7.0 ± 0.4 respectively. A study by Chola.(2020) revealed that the Porridge prepared orange-fleshed sweet potato and finger millet flour were accepted by most panelists for sensory attributes and it was significantly different from the control.

By performing the one-way ANOVA test, it was shown that there is a significant difference between the standard bar and variation I, II and III. The difference is between the organoleptic characteristics like appearance, colour, flavor, taste, texture and overall acceptability ($p < 0.05$).

d. Popped pearl millet bar incorporated with Oriental sweet potato flour

The Table IX presents the mean acceptability score of popped pearl millet bar incorporated with Oriental sweet potato flour

TABLE IX
Mean acceptability Sensory scores of popped pearl millet bar incorporated with Oriental sweet potato flour

Sensory Characteristics	M ± S.D of Sensory score				One-way ANOVA F value	One way ANOVA P value
	Standard (S)	Variation I	Variation II	Variation III		
Appearance	8.87 ± 0.345	8.16 ± 0.592	6.90 ± 0.402	8.76 ± 0.430	120.120	<.001*
Colour	8.66 ± 0.479	7.93 ± 0.520	7.06 ± 0.365	8.70 ± 0.466	83.426	<.001*
Flavour	8.73 ± 0.449	8.23 ± 0.568	7.06 ± 0.365	8.83 ± 0.379	98.218	<.001*
Taste	8.66 ± 0.479	8.10 ± 0.547	7.03 ± 0.556	8.93 ± 0.253	94.109	<.001*
Texture	8.80 ± 0.406	8.13 ± 0.434	6.93 ± 0.520	8.80 ± 0.406	117.574	<.001*
Overall acceptability	8.83 ± 0.379	8.10 ± 0.480	7.03 ± 0.413	8.93 ± 0.253	151.226	<.001*

M±S.D -Mean ± Standard Deviation; * - Significant at 5% level

S-Standard pearl millet bar

Variation I-40% incorporation of sweet potato flour in standard pearl millet bar

Variation II-50% incorporation of sweet potato flour in standard pearl millet bar

Variation III-60% incorporation of sweet potato flour in standard pearl millet bar

With regard to appearance, standard obtained the highest score of 8.8 ± 0.3 followed by variation III, variation I and variation II with scores of 8.7 ± 0.4 , 8.1 ± 0.5 and 6.9 ± 0.4 respectively. With regard to colour variation III scored highest score of 8.7 ± 0.4 followed by standard, variation I and variation II with a score of 8.6 ± 0.4 , 7.9 ± 0.5 and 7.0 ± 0.3 respectively. Variation III scored the highest score of 8.8 ± 0.3 for flavour followed by standard, variation III and variation I with scores of 8.7 ± 0.4 , 8.2 ± 0.5 and 7.0 ± 0.3 respectively. With regard to taste, variation III scored the highest score of 8.9 ± 0.2 followed by standard, variation I and variation II with a score of 8.6 ± 0.4 , 8.1 ± 0.5 and 7.0 ± 0.5 respectively. For texture, the mean acceptability scores of standard and variation III scored highest score of 8.8 ± 0.4 and 8.8 ± 0.4 respectively followed by variation III and variation I with score of 8.1 ± 0.4 and 6.9 ± 0.5 respectively. With regard to overall acceptability of sweet potato popped pearl millet bar, variation III scored the highest score of 8.9 ± 0.2 followed by standard, variation I and variation II with score of 8.8 ± 0.3 , 8.1 ± 0.4 and 7.0 ± 0.4 respectively. A study by Mawouma *et al.* (2022) revealed that the sensory evaluation results of the pearl millet porridge fortified with pearl millet were more favourably appreciated, and a significant increase in the bioaccessibility of iron and zinc at the incorporation rates of 20 and 30% was observed.

By performing the one-way ANOVA test, it was shown that there is a significant difference between the standard bar and variation I, II and III. The difference is between the organoleptic characteristics like appearance, colour, flavor, taste, texture and overall acceptability ($p < 0.05$).

e. Popped sorghum millet bar incorporated with Oriental sweet potato flour

The Table X presents the mean acceptability score of popped sorghum millet bar incorporated with Oriental sweet potato flour

TABLE X

Mean acceptability sensory scores of popped sorghum millet bar incorporated with Oriental sweet potato flour

Sensory Characteristics	M ± S.D of Sensory score				One-Way ANOVA (F value)	One way ANOVA (P value)
	Standard	Variation I	Variation II	Variation III		
Appearance	8.70 ± 0.466	8.13 ± 0.345	7.00 ± 0.00	8.90 ± 0.305	203.155	<.001*
Colour	8.76 ± 0.430	8.13 ± 0.507	7.13 ± 0.571	8.90 ± 0.305	90.428	<.001*
Flavour	8.76 ± 0.430	8.10 ± 0.402	7.06 ± 0.365	8.80 ± 0.406	122.261	<.001*
Taste	8.86 ± 0.345	8.13 ± 0.507	7.26 ± 0.520	8.83 ± 0.379	85.793	<.001*
Texture	8.70 ± 0.466	8.06 ± 0.365	7.13 ± 0.345	8.80 ± 0.40	110.948	<.001*
Overall acceptability	8.83 ± 0.379	7.96 ± 0.319	7.06 ± 0.365	8.90 ± 0.445	175.069	<.001*

M±S.D -Mean ± Standard Deviation; * - Significant at 5% level

S-Standard sorghum millet bar

Variation I-40% incorporation of sweet potato flour in standard sorghum millet bar

Variation II-50% incorporation of sweet potato flour in standard sorghum millet bar

Variation III-60% incorporation of sweet potato flour in standard sorghum millet bar

With regard to appearance , variation 3 scored highest score of 8.9 ± 0.3 followed by standard, variation I and variation II with scores of 8.7 ± 0.4 , 8.1 ± 0.3 and 7.0 ± 0.0 respectively .With regard to colour variation III scored highest score of 8.9 ± 0.3 followed by standard, variation I and variation II with a score of 8.7 ± 0.4 , 8.1 ± 0.5 and 7.1 ± 0.5 respectively .Variation III scored highest score of 8.8 ± 0.4 for flavour followed by standard, variation I and variation II with scores of 8.7 ± 0.4 , 8.1 ± 0.4 and 7.0 ± 0.3 respectively .With regard to taste, standard and variation 3 obtained the highest score of 8.8 ± 0.3 followed by variation I and variation II with scores of 8.1 ± 0.5 and 7.2 ± 0.5 respectively. For the mean acceptability scores of texture variation III scored highest score of 8.8 ± 0.4 followed by standard, variation I and variation II with score of 8.7 ± 0.4 , 8.0 ± 0.3 and 7.1 ± 0.3 respectively. With regard to overall acceptability of sweet potato sorghum finger millet bar, variation 3 scored the highest score of 8.9 ± 0.4 followed by standard, variation I and variation II with score of 8.8 ± 0.3 , 7.9 ± 0.3 and 7.0 ± 0.3 respectively. A study by Tegeye *et al.*(2019) revealed that based upon sensory evaluation, cookies prepared from 40% sweet potato flour and 50% sorghum flour were highly acceptable.By performing the one -way ANOVA test , it was shown that there is a significant difference between the standard bar and variation I , II and III. The difference is between the organoleptic characteristics like appearance, colour, flavor, taste , texture and overall acceptability ($p<0.05$).

f. Sprouted barnyard millet bar incorporated with Hannah sweet potato flour

The Table XI presents the mean acceptability score of sprouted barnyard millet bar incorporated with hannah sweet potato flour

TABLE XI

Mean acceptability scores of sprouted barnyard millet bar incorporated with Hannah sweet potato flour

Sensory Characteristics	M ± S.D of Sensory score				One-Way ANOVA (F value)	One way ANOVA (P value)
	Standard	Variation I	Variation II	Variation III		
Appearance	8.76 ± 0.430	7.10 ± 0.402	8.10 ± 0.402	9.00 ± 0.000	170.792	<.001*
Colour	8.73 ± 0.449	7.20 ± 0.484	8.26 ± 0.520	8.83 ± 0.379	78.729	<.001*
Flavour	8.83 ± 0.379	7.16 ± 0.592	8.23 ± 0.430	8.93 ± 0.253	106.184	<.001*
Taste	8.90 ± 0.305	7.06 ± 0.449	8.23 ± 0.430	8.86 ± 0.345	146.815	<.001*
Texture	8.80 ± 0.406	7.06 ± 0.449	8.23 ± 0.430	8.90 ± 0.305	131.618	<.001*
Overall acceptability	8.80 ± 0.305	6.96 ± 0.413	8.06 ± 0.365	8.90 ± 0.305	205.264	<.001*

M±S.D -Mean ± Standard Deviation; * - Significant at 5% level

S-Standard barnyard millet bar

Variation I-40% incorporation of sweet potato flour in standard barnyard millet bar

Variation II-50% incorporation of sweet potato flour in standard barnyard millet bar

Variation III-60% incorporation of sweet potato flour in standard barnyard millet bar

With regard to appearance, variation 3 scored highest score of 9.0±0.0 followed by standard, variation 2 and variation 1 with scores of 8.7±0.4, 8.1±0.4 and 7.1±0.4 respectively. With regard to colour variation 3 obtained the highest scores of 8.8±0.3 followed by standard, VariationII and variation I with a score of 8.7±0.4,8.2±0.5 and 7.2±0.4 respectively. Variation III scored the highest score of 8.9±0.2 for flavour followed by standard, variation II and variation I with scores of 8.8±0.3 , 8.2±0.4 and 7.1±0.5 respectively .With regard to taste, standard scored the highest score of 8.9±0.3 followed by variation III, variation II and variation I with a score of 8.9±0.4 , 8.2±0.4 and 7.0±0.4 respectively. For texture, the mean acceptability scores of variation III scored highest score of 8.9±0.3 followed by standard, variation II and variation I with scores of 8.8±0.4,8.2±0.4 and 7.0±0.4 respectively. With regard to overall acceptability of sweet potato sprouted barnyard millet bar , variation III scored the highest scores of 8.9±0.3 followed by standard ,variation II and variation I with score of 8.8±0.3,8.0±0.3 and 6.9±0.4 respectively.

By performing the one -way ANOVA test, it was shown that there is a significant difference between the standard bar and variation I , II and III. The difference is between the organoleptic characteristics like appearance ,colour , flavor , taste , texture and overall acceptability (p<0.05).

g. Sprouted foxtail millet bar incorporated with Hannah sweet potato flour

The Table XII presents the mean acceptability score of sprouted foxtail millet bar incorporated with Hannah sweet potato flour

TABLE XII

Mean acceptability sensory Scores of sprouted foxtail millet bar incorporated with Hannah sweet potato flour

Sensory Characteristics	M±S.D.of Sensory score				One-Way ANOVA (F value)	One way ANOVA (P value)
	Standard	Variation I	Variation II	Variation III		
Appearance	8.93±0.379	7.16±0.379	8.86±0.345	8.00±0.262	164.100	<.001*
Colour	8.70±0.466	7.13±0.345	8.80±0.406	8.10±0.402	10.765	<.001*
Flavour	8.90±0.305	7.16±0.461	8.83±0.379	8.16±0.379	130.987	<.001*
Taste	8.86±0.345	7.23±0.504	8.60±0.498	8.30±0.534	67.789	<.001*
Texture	8.70±0.466	7.06±0.365	8.86±0.345	8.06±0.253	149.241	<.001*
Overall acceptability	8.86±0.345	7.06±0.365	8.86±0.445	8.06±0.365	173.209	<.001*

M±S.D -Mean ± Standard Deviation; * - Significant at 5% level

S-Standard foxtail millet bar

Variation I-40% incorporation of sweet potato flour in standard foxtail millet bar

Variation II-50% incorporation of sweet potato flour in standard foxtail millet bar

Variation III-60% incorporation of sweet potato flour in standard foxtail millet bar

With regard to appearance, standard scored highest score of 8.9 ± 0.3 followed by variation II, variation III and variation I with scores of 8.8 ± 0.3 , 8.0 ± 0.2 , 7.1 ± 0.3 respectively. With regard to colour variation II obtained the highest score of 8.8 ± 0.4 followed by standard, variation III and variation I with a score of 8.7 ± 0.4 , 8.1 ± 0.4 and 7.1 ± 0.3 respectively. Standard scored the highest score of 8.9 ± 0.3 for flavour followed by variation II, variation III and variation I with scores of 8.8 ± 0.3 , 8.1 ± 0.3 and 7.1 ± 0.4 respectively. With regard to taste, standard scored the highest score of 8.6 ± 0.3 followed by variation II, variation III and variation I with a score of 8.6 ± 0.4 , 8.3 ± 0.5 and 7.2 ± 0.5 respectively. For texture, the mean acceptability scores of variation II scored highest score of 8.8 ± 0.3 followed by standard, variation III and variation I with score of 8.7 ± 0.4 , 8.0 ± 0.2 and 7.2 ± 0.3 respectively. With regard to overall acceptability of sweet potato sprouted foxtail millet bar, variation II scored the highest scores of 8.8 ± 0.4 followed by standard, variation III and variation I with score of 8.8 ± 0.3 , 8.0 ± 0.3 and 7.0 ± 0.3 respectively.

By performing the one-way ANOVA test, it was shown that there is a significant difference between the standard bar and variation I, II and III. The difference is between the organoleptic characteristics like appearance, colour, flavor, taste, texture and overall acceptability ($p < 0.05$).

h. Popped finger millet bar incorporated with Hannah sweet potato flour

The Table XIII presents the mean acceptability score of popped finger millet bar incorporated with hannah sweet potato flour

TABLE XIII
Mean acceptability sensory scores of popped finger millet bar incorporated with Hannah sweet potato flour

Sensory Characteristics	M \pm S.D of Sensory score				One-Way ANOVA (F value)	One way ANOVA (P value)
	Standard	Variation I	Variation II	Variation III		
Appearance	8.86 ± 0.345	8.93 ± 0.253	7.16 ± 0.379	8.16 ± 0.379	171.737	<.001*
Colour	8.83 ± 0.379	8.80 ± 0.406	7.20 ± 0.484	8.30 ± 0.466	91.644	<.001*
Flavour	8.80 ± 0.406	8.80 ± 0.406	7.27 ± 0.454	8.26 ± 0.449	81.944	<.001*
Taste	8.83 ± 0.379	8.90 ± 0.305	7.16 ± 0.461	8.20 ± 0.406	125.956	<.001*
Texture	8.70 ± 0.466	8.93 ± 0.253	7.10 ± 0.402	8.10 ± 0.305	149.595	<.001*
Overall acceptability	8.90 ± 0.105	8.96 ± 0.382	7.13 ± 0.434	8.13 ± 0.345	201.824	<.001*

M \pm S.D -Mean \pm Standard Deviation; * - Significant at 5% level

S-Standard finger millet bar

Variation I-40% incorporation of sweet potato flour in standard finger millet bar**Variation II-50% incorporation of sweet potato flour in standard finger millet bar****Variation III-60% incorporation of sweet potato flour in standard finger millet bar**

With regard to appearance variation I obtained the highest score of 8.9 ± 0.2 followed by standard, variation III and variation II with scores of 8.8 ± 0.3 , 8.1 ± 0.3 and 7.1 ± 0.3 respectively. Variation I scored the highest score of 8.8 ± 0.4 for colour followed by standard, variation III and variation II with scores of 8.8 ± 0.3 , 8.3 ± 0.4 and 7.2 ± 0.4 respectively. With regard to flavour standard and variation I obtained the highest score of 8.8 ± 0.3 followed by variation III and variation II with a score of 8.2 ± 0.4 and 7.1 ± 0.4 respectively. Variation I scored the highest score of 8.9 ± 0.3 for taste followed by standard, variation III and variation II with scores of 8.8 ± 0.3 , 8.2 ± 0.4 and 7.1 ± 0.4 respectively. For texture, the mean acceptability scores of variation I scored highest score of 8.9 ± 0.2 followed by standard, variation III and variation II with score of 8.7 ± 0.4 , 8.1 ± 0.3 and 7.1 ± 0.4 respectively. With regard to overall acceptability of sweet potato popped finger millet bar, the variation I scored the highest score of 8.9 ± 0.3 followed by standard, variation III and variation I with score of 8.9 ± 0.1 , 8.1 ± 0.3 and 7.1 ± 0.4 respectively.

By performing the one-way ANOVA test, it was shown that there is a significant difference between the standard bar and variation I, II and III. The difference is between the organoleptic characteristics like appearance, colour, flavor, taste, texture and overall acceptability ($p < 0.05$).

i. Popped pearl millet bar incorporated with hannah sweet potato flour

The Table XIV presents the mean acceptability score of popped pearl millet bar incorporated with hannah sweet potato flour

TABLE XIV**Mean acceptability sensory scores of popped pearl millet bar incorporated with Hannah sweet potato flour**

Sensory Characteristics	M ± S.D of Sensory score				One-Way ANOVA (F value)	One way ANOVA (P value)
	Standard	Variation I	Variation II	Variation III		
Appearance	8.73 ± 0.449	8.33 ± 0.479	7.70 ± 0.466	8.80 ± 0.406	37.562	<.001*
Colour	8.80 ± 0.406	8.20 ± 0.406	7.40 ± 0.498	8.73 ± 0.449	64.312	<.001*
Flavour	8.83 ± 0.379	8.23 ± 0.504	7.53 ± 0.628	8.83 ± 0.379	48.998	<.001*
Taste	8.76 ± 0.430	8.26 ± 0.520	7.46 ± 0.571	8.86 ± 0.345	54.517	<.001*
Texture	8.53 ± 0.507	8.16 ± 0.461	7.50 ± 0.572	8.83 ± 0.379	42.054	<.001*
Overall acceptability	8.83 ± 0.379	8.06 ± 0.449	7.10 ± 0.402	8.96 ± 0.182	163.266	<.001*

M±S.D -Mean ± Standard Deviation; * - Significant at 5% level

S-Standard pearl millet bar

Variation I-40% incorporation of sweet potato flour in standard pearl millet bar**Variation II-50% incorporation of sweet potato flour in standard pearl millet bar****Variation III-60% incorporation of sweet potato flour in standard pearl millet bar**

With regard to appearance, variation III obtained the highest score of 8.8 ± 0.4 followed by standard, variation I and variation II with scores of 8.7 ± 0.4 , 8.3 ± 0.4 and 7.7 ± 0.4 respectively. Standard scored the highest score of 8.8 ± 0.4 for colour followed by variation III, variation I and variation II with scores of 8.7 ± 0.4 , 8.2 ± 0.4 and 7.4 ± 0.4 respectively. With regard to flavour standard and variation III obtained the highest score of 8.8 ± 0.3 followed by variation I and variation II with a score of 8.2 ± 0.5 and 7.05 ± 0.6 respectively. Variation III scored the highest score of 8.8 ± 0.3 for taste followed by standard, variation I and variation II with scores of 8.7 ± 0.4 , 8.2 ± 0.5 and 7.4 ± 0.5 respectively. For texture, the mean acceptability scores of variation III obtained the highest score of 8.8 ± 0.3 followed by standard, variation I and variation II with score of 8.5 ± 0.5 , 8.1 ± 0.4 and 7.5 ± 0.5 respectively. With regard to overall acceptability of sweet potato popped pearl millet bar, variation III scored the highest score of 8.9 ± 0.1 followed by standard, variation I and variation II with score of 8.8 ± 0.3 , 8.0 ± 0.4 and 7.1 ± 0.4 respectively.

By performing the one-way ANOVA test, it was shown that there is a significant difference between the standard bar and variation I, II and III. The difference is between the organoleptic characteristics like appearance, colour, flavor, taste, texture and overall acceptability ($p < 0.05$).

j. Popped pearl millet bar incorporated with Hannah sweet potato flour

The Table XV presents the mean acceptability score of popped sorghum millet bar incorporated with hannah sweet potato flour

TABLE XV**Mean scores of Mean acceptability scores of popped sorghum millet bar incorporated with Hannah sweet potato flour**

Sensory Characteristics	M \pm S.D of Sensory score				One-Way ANOVA (F value)	One way ANOVA (P value)
	Standard	Variation I	Variation II	Variation III		
Appearance	8.63 ± 0.379	8.16 ± 0.592	7.66 ± 0.545	8.86 ± 0.479	32.584	<.001*
Colour	8.66 ± 0.305	8.30 ± 0.595	7.60 ± 0.563	8.90 ± 0.479	38.845	<.001*
Flavour	8.75 ± 0.379	8.20 ± 0.484	7.46 ± 0.507	8.85 ± 0.379	65.129	<.001*
Taste	8.73 ± 0.449	8.16 ± 0.461	7.56 ± 0.626	8.90 ± 0.305	48.728	<.001*
Texture	8.69 ± 0.449	8.16 ± 0.379	7.76 ± 0.678	8.76 ± 0.430	27.992	<.001*
Overall acceptability	8.86 ± 0.345	8.06 ± 0.365	7.23 ± 0.626	8.93 ± 0.253	107.837	<.001*

M \pm S.D -Mean \pm Standard Deviation; * - Significant at 5% level

S-Standard sorghum millet bar**Variation I-40% incorporation of sweet potato flour in standard sorghum millet bar**

Variation II-50% incorporation of sweet potato flour in standard sorghum millet bar

Variation III-60% incorporation of sweet potato flour in standard sorghum millet bar

With regard to appearance, variation III scored highest score of 8.8±0.4 followed by standard, variation I and variation II with scores of 8.6±0.3, 8.1±0.5 and 7.6±0.5 respectively. With regard to colour variation III obtained the highest score of 8.9±0.4 followed by standard, variation I and variation II with a score of 8.6±0.3, 8.3±0.5 and 7.6±0.5 respectively. Variation III scored the highest score of 8.8±0.3 for flavour followed by standard, variation I and variation II with scores of 8.7±0.3, 8.2±0.4 and 7.4±0.5 respectively. With regard to taste, variation III scored the highest score of 8.9±0.3 followed by standard, variation I and variation II with a score of 8.7±0.4, 8.1±0.4 and 7.5±0.6 respectively. For texture, the mean acceptability scores of variation III scored highest score of 8.9±0.4 followed by standard, variation I and variation II with score of 8.7±0.4, 8.1±0.3 and 7.7±0.6 respectively. With regard to overall acceptability of sweet potato sprouted barnyard millet bar, variation III scored the highest scores of 8.9±0.2 followed by standard, variation I and variation II with scores of 8.8±0.3, 8.0±0.3 and 7.2±0.6 respectively.

By performing the one-way ANOVA test, it was shown that there is a significant difference between the standard bar and variation I, II and III. The difference is between the organoleptic characteristics like appearance, colour, flavor, taste, texture and overall acceptability (p<0.05).

Phase IV: Nutrient Analysis of the most acceptable Oriental sweet potato flour incorporated bars

a. Analysis of the nutrients of the most acceptable Oriental sweet potato flour incorporated bars

i. Sprouted barnyard millet bar incorporated with Oriental sweet potato flour

Table XVI presents the data on the nutrients present in sprouted barnyard millet bar incorporated with oriental sweet potato flour in comparison with standard millet bar

TABLE XVI

Nutrients present in sprouted barnyard millet bar incorporated with Oriental sweet potato flour in comparison with standard barnyard millet bar

Nutrient	M ± S.D		Paired Sample T test	
	Standard	Product	One-Sided p	Two-Sided p
Moisture(%)	5.4±0.05	6.6±0.02	< .001	.001
Ash(g)	3.1±0.025	4.2±0.025	.004	.007
Energy(Kcal)	357.7±0.40	380.8±0.50	< .001	< .001
Carbohydrate(g)	79.63±0.360	85.2±0.15	< .001	< .001
Protein(g)	2.8±0.754	3.8±0.33	.005	.009
Fat(g)	2.6±0.385	4.0±0.32	.003	.005
Fibre(g)	3.5±0.155	4.7±0.28	.002	.005
Calcium(mg)	63.1±0.380	68.2±0.271	< .001	.002
Iron(mg)	3.5±0.474	4.1±0.05	.003	.006
Vitamin C(mg)	3.3±0.381	4.5±0.015	.005	.010
Beta carotene(µg)	20.2±0.152	180.4±0.450	< .001	< .001

M±S.D -Mean ± Standard Deviation

From the table it is inferred that the moisture content increased from 5.4% to 6.6% and ash content had increased from 3.1g to 4.2g in sprouted barnyard millet bar incorporated with Oriental sweet potato flour. When compared with the standard ,the energy content had increased from 357.7Kcal in the standard product to 380.8Kcal in the most acceptable variation. The carbohydrate and protein content had increased from 79.63g to 85.2g and 2.8g to 3.8g in the most acceptable variation. The fat ad fibre content had increased from 2.6g to 4.0g and 3.5g to 4.7g in the most acceptable variation. The calcium and iron content had increased from 63.1mg to 68.2mg and 3.5mg to 4.1mg in the most acceptable variation when compared with the standard.The vitamin C content had increased from 3.3mg in the standard product to 4.5g in the most acceptable variation.The beta carotene content had significantly increased from 20.2µg in the standard product to 180.4 µg in the most acceptable variation. All the nutrients were enhanced in the sprouted barnyard millet bar incorporated with Oriental sweet potato flour when compared with standard millet bar.

By performing the paired sample t-test, it was shown that there is a significant difference between the standard bar and product. The difference is between the nutrients like moisture, ash , energy, carbohydrate , protein , fat , fibre , calcium , iron and vitamin C and beta-carotene.(p<0.05).

ii. Sprouted foxtail millet bar incorporated with Oriental sweet potato flour

Table XVII presents the data on the nutrients present in sprouted foxtail millet bar incorporated with oriental sweet potato flour in comparison with standard millet bar.

TABLE XVII

Nutrients present in sprouted foxtail millet bar incorporated with Oriental sweet potato flour in comparison with standard foxtail millet bar

Nutrient	M ± S.D		Paired Sample T test	
	Standard	Product	One-Sided p	Two-Sided p
Moisture(%)	6.2±0.522	8.5±0.05	.002	.003
Ash(g)	2.5±0.305	3.8±0.05	.005	.010
Energy(Kcal)	269.9±0.602	344.5±0.251	< .001	< .001
Carbohydrate(g)	56.6±0.213	74.4±0.351	< .001	<.001
Protein(g)	2.6±0.10	3.6±0.360	.001	.002
Fat(g)	2.1±0.030	3.8±0.321	.006	.012
Fibre(g)	1.5±1.19	2.1±0.431	< .001	< .001
Calcium(mg)	47.8±0.486	50.7±0.472	< .001	.002
Iron(mg)	1.8±0.309	3.5±0.210	.001	.002
Vitamin C(mg)	4.3±0.264	4.9±0.057	.006	.012
Beta-carotene(µg)	14.8±0.503	174.7±0.450	< .001	< .001

M±S.D -Mean ± Standard Deviation

From the table it is inferred that the moisture content increased from 6.2% to 8.5% and ash content had increased from 2.5g to 3.8g in sprouted foxtail millet bar incorporated with Oriental sweet potato flour. When compared with the standard millet bar the energy content had increased from 269.9Kcal in the standard product to 344.5Kcal in the most acceptable variation. The carbohydrate and protein content had increased from 56.6g to 74.4g and 2.6g to 3.6g in the most acceptable variation. The fat and fibre content had increased from 2.1 to 3.8g and 1.5g to 2.1g in the most acceptable variation. The calcium and iron content had increased from 47.8mg to 50.7mg and 1.8mg to 3.5mg in the most acceptable variation when compared with the standard. The vitamin C content had increased from 4.3mg in the standard product to 4.8g in the most acceptable variation. The beta carotene content had significantly increased from 14.8 μ g in the standard product to 174.7 μ g in the most acceptable variation. All the nutrients were enhanced in the sprouted foxtail millet bar incorporated with Oriental sweet potato flour when compared with standard.

By performing the paired sample t-test , it was shown that there is a significant difference between the standard bar and product. The difference is between the nutrients like moisture , ash , energy, carbohydrate , protein , fat , fibre , calcium , iron and vitamin Cand beta-carotene.(p<0.05).

iii. popped finger millet bar incorporated with Oriental sweet potato flour

Table XVIII presents the data on the nutrients present in popped finger millet bar incorporated with oriental sweet potato flour in comparison with standard millet bar.

TABLE XVIII

Nutrients present in popped finger millet bar incorporated with Oriental sweet potato flour in comparison with standard finger millet bar

Nutrient	M \pm S.D		Paired Sample T test	
	Standard	Product	One-Sided p	Two-Sided p
Moisture (%)	6.2 \pm 0.33	7.5 \pm 0.12	.001	.003
Ash(g)	3.2 \pm 0.680	3.7 \pm 0.05	.005	.010
Energy (Kcal)	284 \pm 0.41	348.8 \pm 1.60	< .001	< .001
Carbohydrate(g)	63.3 \pm 0.444	74.2 \pm 0.42	< .001	.001
Protein(g)	4.5 \pm 0.382	5.4 \pm 0.20	.002	.004
Fat(g)	2.3 \pm 0.364	3.1 \pm 0.20	.003	.006
Fibre(g)	1.3 \pm 0.09	3.6 \pm 0.26	.003	.005
Calcium(mg)	125.4 \pm 0.614	151.1 \pm 0.45	< .001	< .001
Iron(mg)	2.1 \pm 0.198	3.4 \pm 0.26	.006	.013
Vitamin C(mg)	3.2 \pm 0.351	4.0 \pm 0.041	.003	.005
Beta-carotene(μ g)	17.5 \pm 0.305	140.5 \pm 0.32	< .001	< .001

M \pm S.D -Mean \pm Standard Deviation

The data in the table reveals that the moisture content increased from 6.2% to 7.5% and ash content had increased from 3.2g to 3.7g in sprouted finger millet bar incorporated with Oriental sweet potato flour

when compared with the standard millet bar. The energy content had increased from 284Kcal in the standard product to 348.8Kcal in the most acceptable variation. The carbohydrate and protein content had increased from 63.3g to 74.2g and 4.5g to 5.4g in the most acceptable variation. The fat and fibre content had increased from 2.3g to 3.1g and 1.3g to 3.6g in the most acceptable variation. The calcium and iron content had increased from 125.4mg to 151.1mg and 2.1mg to 3.4mg in the most acceptable variation. The vitamin C content had increased from 3.2mg in the standard product to 4.0g in the most acceptable variation. The beta had significantly increased from 17.5µg in the standard product to 140.5 µg in the most acceptable variation. All the nutrients were enhanced in the popped finger millet bar incorporated with Oriental sweet potato flour when compared with standard.

By performing the paired sample t-test , it was shown that there is a significant difference between the standard bar and product. The difference is between the nutrients like moisture, ash, energy, carbohydrate , protein , fat , fibre , calcium , iron and vitamin C and beta-carotene.(p<0.05).

iv. Popped pearl millet bar incorporated with Oriental sweet potato flour

Table XIX presents the data on the nutrients present in popped pearl millet bar incorporated with oriental sweet potato flour in comparison with standard millet bar.

TABLE XIX

Nutrients present in popped pearl millet bar incorporated with Oriental sweet potato flour in comparison with standard pearl millet bar

Nutrient	M ± S.D		Paired Sample T test	
	Standard	Product	One-Sided p	Two-Sided p
Moisture(%)	4.5±0.124	6.3±0.10	< .001	.001
Ash(g)	2.5±0.305	3.7±0.10	.009	.018
Energy(Kcal)	290.8±0.70	367.1±1.040	.001	.001
Carbohydrate(g)	60.0±0.619	74.6±0.152	< .001	< .001
Protein(g)	2.7±0.335	5.7±0.152	< .001	.002
Fat(g)	2.7±0.248	4.7±0.20	.003	.005
Fibre(g)	1.4±0.077	5.6±0.624	.004	.009
Calcium(mg)	62.4±0.10	68.2±0.70	.003	.007
Iron(mg)	3.6±0.251	8.9±0.251	.002	.003
Vitamin C(mg)	3.2±0.351	4.2±0.266	.004	.009
Beta-carotene(µg)	56.41±0.351	210.6±0.458	< .001	< .001

M±S.D -Mean ± Standard Deviation

From the data on nutrient analysis it is revealed that the moisture content increased from 4.5% to 6.3% and ash content had increased from 2.5g to 3.7g in popped pearl millet bar incorporated with Oriental sweet potato flour when compared with the standard millet bar. The energy content had increased from 290.8Kcal in the standard product to 367.1Kcal in the most acceptable variation. The carbohydrate and protein content had increased from 60.0g to 74.6g and 2.7g to 5.7g in the most

acceptable variation. The fat and fibre content had increased from 2.7g to 4.7g and 1.4g to 5.6g in the most acceptable variation. The calcium and iron content had increased from 62.4mg to 68.2mg and 3.6mg to 8.8mg in the most acceptable variation when compared with standard. The vitamin C content had increased from 3.2mg in the standard product to 4.2mg in the most acceptable variation. All the nutrients were enhanced in the popped finger millet bar incorporated with Oriental sweet potato flour when compared with standard.

By performing the paired sample t-test, it was shown that there is a significant difference between the standard bar and product. The difference is between the nutrients like moisture, ash, energy, carbohydrate, protein, fat ,fibre , calcium , iron and vitamin C and beta-carotene.($p < 0.05$).

v.Popped sorghum millet bar incorporated with Oriental sweet potato flour

Table XX presents the data on the nutrients present in popped sorghum millet bar incorporated with oriental sweet potato flour in comparison with standard millet bar.

TABLE XX

Nutrients present in popped sorghum millet bar incorporated with Oriental sweet potato flour in comparison with standard sorghum millet bar

Nutrient	M ± S.D		Paired Sample T test	
	Standard	Product	One-Sided p	Two-Sided p
Moisture(%)	5.3±0.120	6.82±0.10	< .001	.001
Ash(g)	2.5±0.20	3.4±0.022	.008	.016
Energy(Kcal)	301.3±0.332	385.5±0.115	< .001	< .001
Carbohydrate(g)	70.4±0.317	85.2±0.120	< .001	< .001
Protein(g)	3.6±0.282	4.2±0.248	.003	.006
Fat(g)	2.0±0.054	3.4±0.267	.008	.017
Fibre(g)	1.5±0.054	2.7±0.092	< .001	.002
Calcium(mg)	60.8±0.534	65.4±0.350	.004	.008
Iron(mg)	1.8±0.264	4.4±0.494	< .001	.002
Vitamin C(mg)	3.2±0.251	4.2±0.228	.007	.014
Beta-carotene(µg)	21.56±0.351	190.7±0.416	< .001	< .001

M±S.D -Mean ± Standard Deviation

From the data on nutrient analysis it is revealed that the moisture content increased from 5.3% to 6.8% and ash content had increased from 2.5g to 3.4g in popped sorghum millet bar incorporated with Oriental sweet potato flour. When compared with the standard millet bar, the energy content had increased from 301.3Kcal in the standard product to 385.5Kcal in the most acceptable variation. The carbohydrate and protein content had increased from 70.4g to 85.2g and 3.6g to 4.2g in the most acceptable variation. The fat and fibre content had increased from 2.0g to 3.4g and 1.5g to 2.7g in the most acceptable variation. The calcium and iron content had increased from 60.8mg to 65.4mg and 1.8mg to 4.4mg in the most acceptable variation. The vitamin C content had increased from 3.2mg in

the standard product to 4.2mg in the most acceptable variation. All the nutrients were enhanced in the popped sorghum millet bar incorporated with Oriental sweet potato flour when compared with standard.

By performing the paired sample t-test, it was shown that there is a significant difference between the standard bar and product. The difference is between the nutrients like moisture, ash, energy, carbohydrate, protein, fat, fibre, calcium, iron and vitamin C and beta-carotene($p < 0.05$).

PHASE V: Microbial analysis, Color analysis, Texture characteristics and shelf - life testing of the Oriental and Hannah sweet potato millet bars

a. Analysis of the microbial content of the Oriental and Hannah sweet potato millet bars

Table XXI represents the total plate count of Oriental and Hannah sweet potato millet bars:

TABLE XXI

Total Plate Count of Oriental and Hannah sweet potato millet bars

S.No	Sample	Microbial count (Total plate count)		
		Day 0	Day 15	Day 30
Millet bars incorporated with Oriental sweet potato flour				
1.	SBY	0	7.2×10^5 cfu/g	15.4×10^5 cfu/g
2.	SFT	0	5.2×10^5 cfu/g	13.3×10^5 cfu/g
3.	SFM	0	8.2×10^5 cfu/g	16.3×10^5 cfu/g
4.	SPM	0	7.1×10^5 cfu/g	15.3×10^5 cfu/g
5.	SSM	0	5.1×10^5 cfu/g	13.3×10^5 cfu/g
Millet bars incorporated with Hannah sweet potato flour				
6.	SBY	0	7.2×10^5 cfu/g	15.4×10^5 cfu/g
7.	SFT	0	5.2×10^5 cfu/g	13.3×10^5 cfu/g
8.	SFM	0	8.2×10^5 cfu/g	16.3×10^5 cfu/g
9.	SPM	0	7.1×10^5 cfu/g	15.3×10^5 cfu/g
10.	SSM	0	5.1×10^5 cfu/g	13.3×10^5 cfu/g

SBY- Sweet potato sprouted barnyard millet bar

SFT- Sweet potato sprouted foxtail millet bar

SFM- Sweet potato popped finger millet bar

SPM- Sweet potato popped pearl millet bar

SSM-Sweet potato popped sorghum millet bar

The data related to microbial analysis of the Oriental and Hannah sweet potato millet bars are presented in table XXI. It was evident from the data on the total plate count of the Oriental and Hannah sweet potato flour incorporated millet bars. The microbial analysis of the Oriental and Hannah sweet potato millet bars were evaluated at day 0, day 15 and day 30. From the analysis it is evident that the total plate count in day 0 experimental samples were 100% negative. Microbial analysis becomes an important issue from safety point of view in all food processing and product formulations.

The total plate count is similar among the Oriental and Hannah sweet potato flour incorporated millet bars.

On the 15th day the maximum total plate count was observed in SFT with a value of 8.2×10^5 cfu/g followed by SBY, SFM, SPM AND SSM with values of 7.2×10^5 cfu/g, 6.1×10^5 cfu/g, 5.2×10^5 cfu/g and 5.1×10^5 cfu/g respectively.

On the 30th day the maximum total plate count was observed in SFT with a value of 16.3×10^5 cfu/g followed by SBY, SFM, SPM AND SSM with values of 15.4×10^5 cfu/g, 14.1×10^5 cfu/g, 13.3×10^5 cfu/g and 12.2×10^5 cfu/g respectively on the 30th day.

Low microbial growth was observed after 30 days of storage as the product has long shelf life and it can be inferred from the results that all the Oriental and Hannah sweet potato millet bars can be used for upto 30 days.

b. Color analysis of the prepared Oriental and Hannah sweet potato millet bars:

Color differences between the Oriental and Hannah potato millet bars are shown in the table XXII.

TABLE XXII

Colour Analysis of the Oriental and Hannah sweet potato millet bars

Millet bars with Oriental and Hannah sweet potato flour	Colour Analysis		
	L* M±SD	a* M±SD	b* M±SD
Millet bars incorporated with Oriental sweet potato flour			
SBY	26.74±0.05	5.30±0.10	1.3±0.057
SFT	25.85±0.010	4.66±0.010	1.05±0.010
SFM	24.52±0.020	3.50±0.10	2.05±0.010
SPM	21.19±0.05	3.48±0.010	3.06±0.010
SSM	23.59±0.060	3.4±0.435	1.5±0.10
Millet bars incorporated with Hannah sweet potato flour			
SBY	27.50±0.10	5.6±0.10	0.80±0.10
SFT	26.85±0.010	4.66±0.010	1.06±0.010
SFM	23.53±0.057	4.20±0.010	1.16±0.152
SPM	22.19±0.057	3.83±0.057	2.06±0.010
SSM	22.59±0.060	4.4±0.435	1.5±0.10

M±S.D -Mean ± Standard Deviation

Note: L* - Lightness from black to white, a*-Green to red,b*-Blue to yellow

SBY- Sweet potato flour incorporated sprouted barnyard millet bar

SFT- Sweet potato flour incorporated sprouted foxtail millet bar

SFM- Sweet potato flour incorporated popped finger millet bar

SPM- Sweet potato flour incorporated popped pearl millet bar

SSM-Sweet potato flour incorporated popped sorghum millet bar

The ‘L’ value for colour represents the black-white axis. All the oriental and Hannah sweet flour incorporated millet bars had positive value and were lighter in colour with higher L* values. The

‘a’ value for colour represents the red-green axis. All the oriental and Hannah sweet flour incorporated millet bars had the positive a* value and were therefore slightly red. The ‘b’ values measure the blue-yellow axis. All variables of the b* value were positive, and therefore were slightly yellow. Since the samples were coated with dark chocolate the coated samples had lower b* values.

c. Analysis of the texture characteristics of the prepared Oriental and Hannah sweet potato millet bars

Textural properties of food are necessary for the development of a product. The textural qualities such as are hardness and adhesiveness present in the Oriental and Hannah sweet potato millet bars were analyzed by Texture Analyzer SHIMANDZU EZ-XS. The textural characteristics are generally influenced by the drying temperature and moisture content. Texture profile analysis is a convenient method for evaluation of food texture. Table XXIII depicts the texture analysis of the Oriental and Hannah sweet potato flour incorporated millet bars.

TABLE XXIII
Texture Profile analysis of the Oriental and Hannah sweet potato millet bars

Products	Test mode	Speed	Test type	Shape	Hardness Average	Adhesiveness Average
Millet bars incorporated with Oriental sweet potato flour						
SBY	Texture	1mm/sec	3 Point bend	Plate	3.878	0.010
SFT	Texture	1mm/sec	3 Point bend	Plate	4.174	0.045
SFM	Texture	1mm/sec	3 Point bend	Plate	1.266	0.043
SPM	Texture	1mm/sec	3 Point bend	Plate	7.441	0.012
SSM	Texture	1mm/sec	3 Point bend	Plate	4.253	0.013
Millet bars incorporated with Hannah sweet potato flour						
Products	Test mode	Speed	Test type	Shape	Hardness average	Adhesiveness average
SBY	Texture	1mm/sec	3 Point bend	Plate	1.616	0.010
SFT	Texture	1mm/sec	3 Point bend	Plate	3.637	0.015
SFM	Texture	1mm/sec	3 Point bend	Plate	1.226	0.011
SPM	Texture	1mm/sec	3 Point bend	Plate	1.710	0.034
SSM	Texture	1mm/sec	3 Point bend	Plate	5.952	0.018

SBY- Sweet potato flour incorporated sprouted barnyard millet bar

SFT- Sweet potato flour incorporated sprouted foxtail millet bar

SFM- Sweet potato flour incorporated popped finger millet bar

SPM- Sweet potato flour incorporated popped pearl millet bar

SSM- Sweet potato flour incorporated popped sorghum millet bar

In comparison between the oriental and Hannah sweet potato flour incorporated millet bars, the hardness and adhesiveness values of Oriental sweet flour incorporated millet bars were higher.

Among the Oriental sweet potato flour incorporated millet bars, the hardness values were observed to be high in the order of SPM, SBY,SSM, SFT and SFM. The adhesiveness values were observed to be high in the order of SFT, SFM, SSM, SPM and SBY.

Among the Hannah sweet potato flour incorporated millet bars, the hardness Values were observed to be high in the order of SSM,SFT, SPM, SBY and SFM.The adhesiveness values were observed to be high in the order of SPM, SSM, SFM, SFT and SBY. Figure 6 represents the texture analysis of Oriental and Hannah sweet potato flour incorporated millet bars:

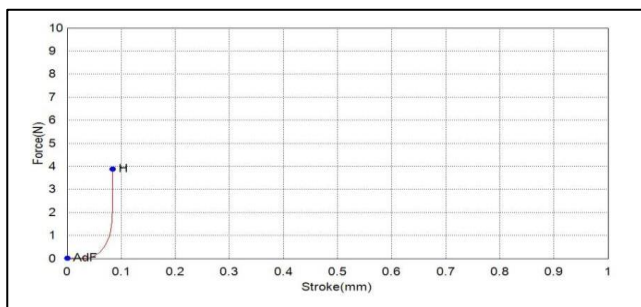


Fig 6.1 OSBY

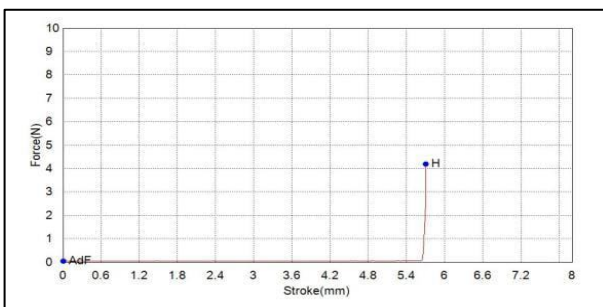


Fig 6.2 OSFT

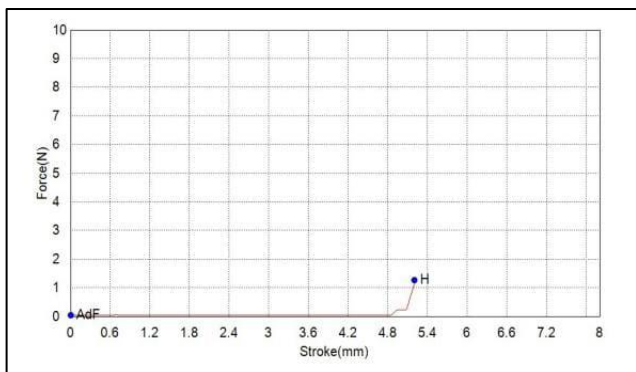


Fig 6.3 OSFM

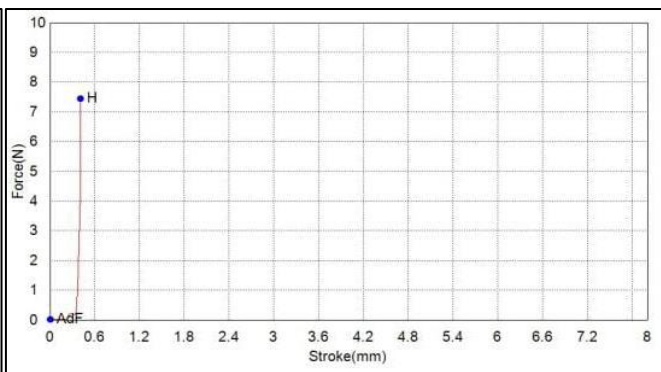


Fig 6.4 OSPM

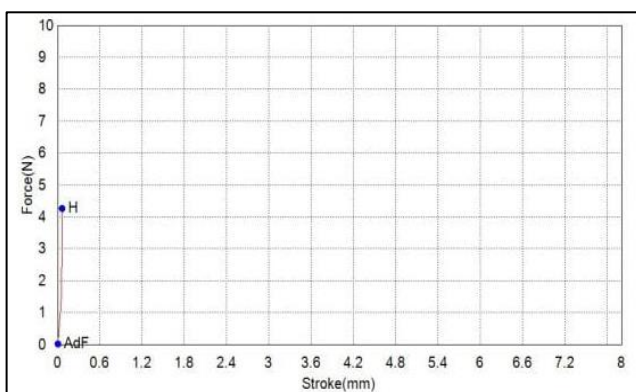


Fig 6. OSSM

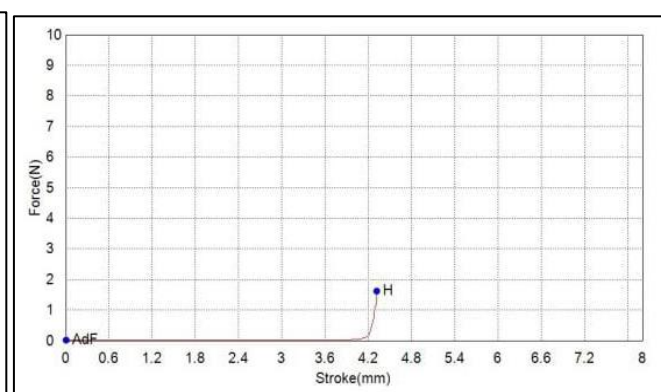


Fig 6.6 HSBY

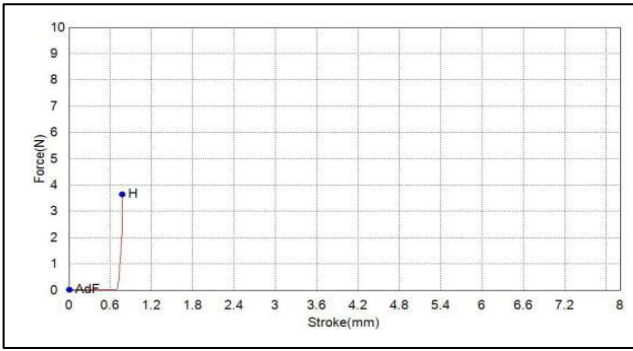


Fig 6.7 HSFT

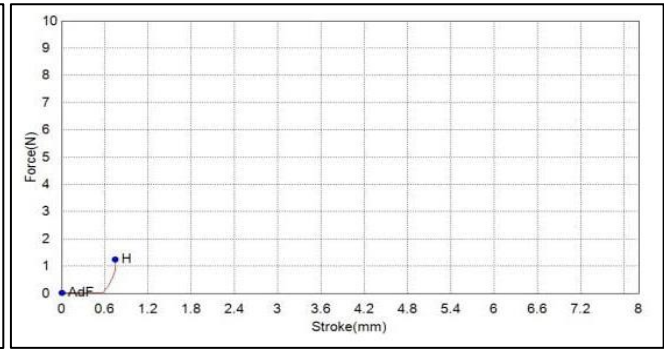


Fig 6.8 HSFM

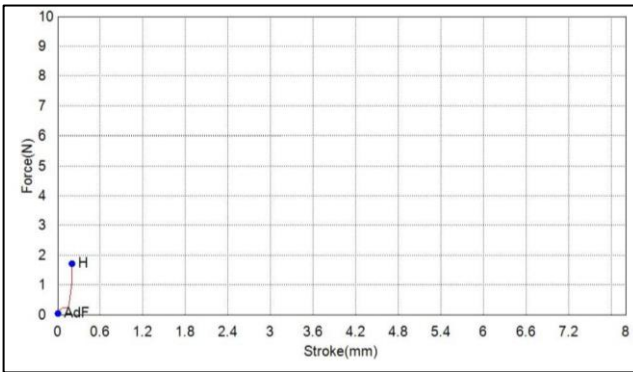


Fig 6.9 HSPM

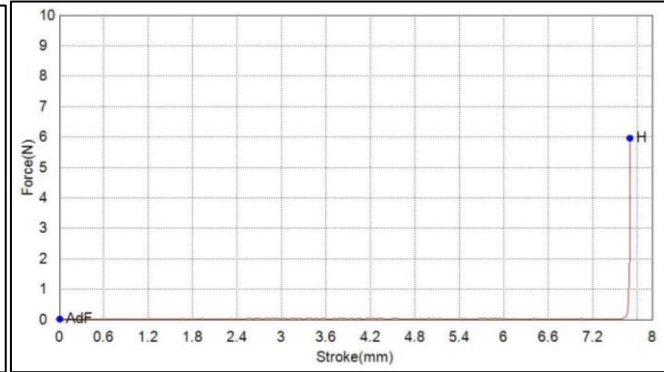


Fig 6.10 HSSM

Figure 6: Texture analysis of Oriental and Hannah sweet potato flour incorporated millet bars

OSBY- Oriental Sweet potato flour incorporated sprouted barnyard millet bar

OSFT- Oriental Sweet potato flour incorporated sprouted foxtail millet bar

OSFM- Oriental Sweet potato flour incorporated popped finger millet bar

OSPM- Oriental Sweet potato flour incorporated popped pearl millet bar

OSSM- Oriental Sweet potato flour incorporated popped sorghum millet bar

HSBY- Hannah Sweet potato flour incorporated sprouted barnyard millet bar

HSFT- Hannah Sweet potato flour incorporated sprouted foxtail millet bar

HSFM- Hannah Sweet potato flour incorporated popped finger millet bar

HSPM- Hannah Sweet potato flour incorporated popped pearl millet bar

HSSM- Hannah Sweet potato flour incorporated popped sorghum millet bar

d. Shelf - life testing of the developed food products

Shelf life of the product was determined by Q10 values. Q10 is the factor by which the rate of reaction increased when the temperature was raised by 10 degrees. Table XXIV revealed the variations in moisture content during storage period of 30 days.

TABLE XXIV

Variations in moisture content of Oriental sweet potato flour incorporated millet bars during storage period of 30days

Product	Parameter	Temp in °C	Number of days of storage				Rate of reaction	Q10	Predicted shelf life (in months)
			0 day	5 th day	15 th day	30 th day			
Oriental sweet potato flour incorporated millet bars									
SBY	Moisture (%)	T1	6.22	6.4	6.95	7.02	0.07	0.7	2.57
		T2	6.22	6.2	6.50	6.89	0.1		
SFT	Moisture (%)	T1	6.53	6.77	6.90	7.12	0.05	0.8	2.94
		T2	6.53	6.60	6.80	7.05	0.06		
SFM	Moisture (%)	T1	5.92	6.20	6.55	6.89	0.11	0.3	1.10
		T2	5.92	6.10	6.35	6.70	0.33		
SPM	Moisture (%)	T1	7.35	7.55	7.75	8.05	0.03	0.7	2.57
		T2	7.35	7.40	7.64	7.90	0.04		
SSM	Moisture (%)	T1	6.76	6.98	7.20	7.50	0.04	0.8	2.94
		T2	6.76	6.86	7.10	7.35	0.05		

T1 – 45°C, T2 – ambient temperature

SBY- Sweet potato flour incorporated sprouted barnyard millet bar

SFT- Sweet potato flour incorporated sprouted foxtail millet bar

SFM- Sweet potato flour incorporated popped finger millet bar

SPM- Sweet potato flour incorporated popped pearl millet bar

SSM- Sweet potato flour incorporated popped sorghum millet bar

In Oriental sweet potato flour incorporated millet bars, for SBY, the rate of reaction for moisture at 45°C was 0.07 and at 35°C was 0.1. Q10 value for change in the moisture percentage was found to be 0.7. For SFT, the rate of reaction for moisture at 45°C was 0.05 and at 35°C was 0.06. Q10 value for change in the moisture percentage was found to be 0.8. For SFM, the rate of reaction for moisture at 45°C was 0.11 and at 35°C was 0.33. Q10 value for change in the moisture percentage was found to be 0.3. For SPM, the rate of reaction for moisture at 45°C was 0.03 and at 35°C was 0.04. Q10 value for change in the moisture percentage was found to be 0.7. For SSM, the rate of reaction for moisture at 45°C was 0.04 and at 35°C was 0.05. Q10 value for change in the moisture percentage was found to be 0.8.

The Oriental sweet potato millet bars were stored in LDPE laminated stand up paper pouches in the incubator (45°C) and ambient temperature (14-35°C). During storage (0-30days) the moisture content was observed to be increased in all the sweet potato millet bars. In Oriental sweet potato flour

incorporated millet bars during 30 days of storage, the moisture gain was 0.8% and 0.6%, 0.9% and 0.5%, 1.0% and 0.78%, 0.7% and 0.5%, 0.7% and 0.6% for SBY, SFT, SFM, SPM and SSM respectively which indicates moisture gain of samples at accelerated condition was significantly higher compared to samples stored at high temperature and high relative humidity the products absorb moisture. It can be concluded that in the sweet potato flour incorporated millet bars which was packed in LDPE laminated stand up paper pouches, the SBY has a shelf life of 2.57 months, the SFT has a shelf life of 2.94 months, the SFM has a shelf life of 1.10 months, the SPM has a shelf life of 2.57 months and SSM has a shelf life of 2.94 months.

TABLE XXV

Variations in moisture content of Hannah sweet potato flour incorporated millet bars during storage period of 30 days

Samples	Parameter	Temp in °C	Number of days of storage				Rate of reaction	Q10	Predicted shelf life (in months)
			0 day	5 th day	15 th day	30 th day			
Hannah sweet potato flour incorporated millet bars									
SBY	Moisture (%)	T1	6.17	6.33	6.52	6.82	0.06	0.6	2.20
		T2	6.17	6.29	6.47	6.61	0.09		
SFT	Moisture (%)	T1	6.50	6.72	6.95	7.10	0.04	0.8	2.94
		T2	6.50	6.65	6.80	6.92	0.05		
SFM	Moisture (%)	T1	5.80	5.95	6.18	6.30	0.10	0.6	2.20
		T2	5.80	5.89	6.00	6.12	0.16		
SPM	Moisture (%)	T1	7.29	7.45	7.78	7.99	0.03	0.7	2.57
		T2	7.29	7.32	7.51	7.82	0.04		
SSM	Moisture (%)	T1	6.72	6.96	7.19	7.35	0.04	0.8	2.94
		T2	6.72	6.85	7.05	7.15	0.05		

T1 – 45°C, T2 – ambient temperature

Table XXVIII revealed the variations in moisture content during storage period of 30 days. In Hannah sweet potato flour incorporated millet bars, for SBY, the rate of reaction for moisture at 45°C was 0.06 and at 35°C was 0.09. Q10 value for change in the moisture percentage was found to be 0.6. For SFT, the rate of reaction for moisture at 45°C was 0.04 and at 35°C was 0.05. Q10 value for change in the moisture percentage was found to be 0.8. For SFM, the rate of reaction for moisture at 45°C was 0.10 and at 35°C was 0.16. Q10 value for change in the moisture percentage was found to be 0.6. For SPM, the rate of reaction for moisture at 45°C was 0.03 and at 35°C was 0.04. Q10 value for change in the moisture percentage was found to be 0.7. For SSM, the rate of reaction for moisture at

45°C was 0.04 and at 35°C was 0.05. Q10 value for change in the moisture percentage was found to be 0.8.

The Hannah sweet potato millet bars were stored in LDPE laminated stand up paper pouches in the incubator (45°C) and ambient temperature (14-35°C). During storage (0-30 days) the moisture content was observed to be increased in all the sweet potato millet bars.

In Hannah sweet potato flour incorporated millet bars during 30 days of storage, the moisture gain was 0.6% and 0.4%, 0.6% and 0.4%, 0.5% and 0.32%, 0.7% and 0.5%, 0.6% and 0.4% for SBY, SFT, SFM, SPM and SSM respectively which indicates moisture gain of samples at accelerated condition was significantly higher compared to samples stored at high temperature and high relative humidity the products absorb moisture.

It can be concluded that the in the hannah sweet potato flour incorporated millet bars which was packed in LDPE laminated stand up paper pouches, the SBY has a shelf life of 2.20 months, the SFT has a shelf life of 2.94 months, the SFM has a shelf life of 2.20 months, the SPM has a shelf life of 2.57 months and SSM has a shelf life of 2.94 months.

Summary and conclusion

V. SUMMARY AND CONCLUSION

The present study entitled “Formulation of Beta Carotene and Fibre Rich Nutritious Bar Using Sweet Potato (*Ipomoea batatas*) and Millets represents the work on Oriental and Hannah sweet potato flour which are rich in β -Carotene, high in energy and has rated to be a good biological value and millets such as barnyard millet, foxtail millet, finger millet, pearl millet and sorghum millet which are high in fibre, low in glycemic index and contain various bioactive compounds. The present investigation was therefore undertaken to assess the phytochemical profile, functional properties, and nutrient content of Oriental and Hannah sweet potato flour. Formulation, standardization and organoleptic evaluation of the Oriental and Hannah sweet potato flour incorporated millet bars were carried out. Based on the nutrient and phytochemical profile of the sweet potato flours, the most acceptable Oriental sweet potato flour incorporated millet bars were subjected to nutrient analysis. The analysis of microbial content, colour, texture characteristics and shelf-life study was carried out for both the oriental and Hannah sweet potato flour incorporated millet bars.

The present study was conducted with the following objectives:

- To prepare fibre rich millet bars by incorporating sweet potato flour.
- To analyse the nutrients and phytochemicals present in the Oriental and Hannah varieties of the sweet potato flour
- To analyse the organoleptic characteristics of different sweet potato millet bars prepared.
- To analyse the microbial content, texture characteristics and shelf life of the prepared sweet potato millet bars.

Oriental and Hannah sweet potatoes were selected based on the local availability and the amount of research previously done on them. Fresh Oriental and Hannah sweet potatoes with no bruises or cracks were procured from the local area. The procured sweet potatoes were subjected to different processing steps like cleaning, drying and powdering.

The Oriental and Hannah sweet potatoes were collected from the local area of Saibaba colony, Coimbatore. The sweet potatoes were dried in the cabinet drier until free from moisture, then powdered into flour and stored in an air tight container. The Oriental and Hannah sweet potato flours were subjected to analysis of functional properties such as water absorption capacity, oil absorption capacity and swelling power.

The samples were subjected to qualitative analysis of phytochemical constituents in ethanol extracts. The phytochemical compounds analyzed were alkaloids, flavonoids, saponins, tannins, terpenoids, anthraquinones and phenolic compounds.

Dried samples were used for the analysis of nutrients like moisture, ash, energy, carbohydrate, protein, fat, fibre, calcium, iron, vitamin C and beta carotene by following the AOAC (The Association of Official Analytical Chemists) method. The diluted ash samples were used for the analysis of micronutrients.

Millet bars such as sprouted barnyard bar, sprouted foxtail bar, popped finger millet bar, popped pearl millet bar and popped sorghum millet bar were prepared with the incorporation of Oriental and Hannah sweet potato flour. Standard and variation of the prepared products were evaluated based on the nine-point hedonic rating scale for sensory attributes like appearance, colour, flavour, texture, taste and overall acceptability by ten members for successive three trials. The products were incorporated with 40,50 and 60g of Oriental and Hannah sweet potato flour into the standard millet bars.

Based on the nutrient and phytochemical profile of the sweet potato flours, the most acceptable Oriental sweet potato flour incorporated millet bars were subjected to nutrient analysis. The analysis of microbial content, colour, texture characteristics and shelf-life study were carried out for both the oriental and Hannah sweet potato flour incorporated millet bars.

Salient findings of the study:

- Hundred grams of Oriental and Hannah sweet potato were taken and it was dried and powdered. The powdered oriental and Hannah sweet potato flour obtained from 100g was 25% of the original weight.
- The water absorption capacity of Oriental and Hannah sweet potato flour was 295g and 250g respectively. The oil absorption capacity of Oriental and Hannah sweet potato flour was 110g and 95g respectively. The swelling capacity of Oriental and Hannah sweet potato flour was 3.45g and 3.35g respectively. The water absorption capacity, oil absorption capacity and swelling capacity of oriental sweet potato flour was higher when compared to Hannah sweet potato flour.
- Oriental and Hannah sweet potato flour extracts indicated the presence of alkaloids, flavonoids, saponins, tannins, terpenoids and phenolic compounds. Oriental and Hannah sweet potato flour extracts indicated the absence of Anthraquinones.
- Moisture content of oriental and hannah sweet potato flour was 6.7% and 6.3% respectively. Ash content of oriental and hannah sweet potato flour was 1.4g and 1.3g respectively. Energy value of oriental and hannah sweet potato flour was 381.5Kcal and 365.3Kcal respectively. Carbohydrate content of oriental and hannah sweet potato flour was 86.6g and 85g respectively. Protein content of oriental and hannah sweet potato flour was 4.7g and 3.6g respectively.. Fat content of oriental and hannah sweet potato flour was 4.4g and 4.2g respectively. Fibre content of oriental and hannah sweet potato flour was 4.4g and 3.5g respectively. Calcium content of the oriental and hannah sweet potato

flour was 8.7mg and 6.0mg respectively. Iron content of the oriental and hannah sweet potato flour was 8.8mg and 7.2mg and respectively. Vitamin C content of the oriental and hannah sweet potato flour was 2.7mg and 2.2mg respectively. Beta carotene content of oriental and hannah sweet potato flour was 350µg and 60 µg respectively. All the nutrients were higher in Oriental sweet potato flour when compared to the hannah sweet potato flour.

- Hundred grams of fresh sample of the barnyard and foxtail millet was taken and the sprouted flour obtained from 100 g of the barnyard and foxtail millet was 90% of the original weight. Hundred grams of fresh sample of the finger millet, pearl millet and sorghum millet were taken and the popping yield of finger millet, pearl millet and sorghum millet were 80%,60% and 40% respectively.
- Organoleptic evaluation of oriental and hannah sprouted barnyard millet bar revealed that incorporation of 60% sweet potato flour was found to have high overall acceptability in terms of appearance, colour, flavour, taste and texture which is statistically significant when compared with the standard with a p value of <0.05.
- Organoleptic evaluation of oriental and hannah sprouted foxtail millet bar revealed that incorporation of 50% sweet potato flour was found to have high overall acceptability in terms of appearance, colour, flavour, taste and texture which is statistically significant when compared with the standard with a p value of <0.05.
- Organoleptic evaluation of oriental and hannah popped finger millet bar revealed that incorporation of 40% sweet potato flour was found to have high overall acceptability in terms of appearance, colour, flavour, taste and texture which is statistically significant when compared with the standard with a p value of <0.05.
- Organoleptic evaluation of oriental and hannah popped pearl millet bar revealed that incorporation of 60% sweet potato flour was found to have high overall acceptability in terms of appearance, colour, flavour, taste and texture which is statistically significant when compared with the standard with a p value of <0.05.
- Organoleptic evaluation of oriental and hannah popped sorghum millet bar revealed that incorporation of 60% sweet potato flour was found to have high overall acceptability in terms of appearance, colour, flavour, taste and texture which is statistically significant when compared with the standard with a p value of <0.05.
- Moisture content of Oriental sweet potato millet bars increased significantly ($p<0.05$) compared to the standard due to the addition of sweet potato flour. Moisture content was increased from 5.4% to 6.6% in SBY, 6.2% to 8.5% in SFT, 6.2% to 7.5% in SFM, 4.5% to 6.3% in SPM and 5.3% to 6.8% in SSM.

- Ash content of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) compared to the standard due to the addition of sweet potato flour. Ash content was increased from 3.1g to 4.2g in SBY, 2.5g to 3.8g in SFT, 3.2g to 3.7g in SFM, 2.5g to 3.7g in SPM and 2.5g to 3.4g in SSM.
- Energy value of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) from 357.7Kcal to 380.8Kcal in SBY, 269.9Kcal to 344.5Kcal in SFT, 284Kcal to 348.8Kcal in SFM, 290.8Kcal to 367.1Kcal in SPM and 301.3Kcal to 385.5Kcal in SSM.
- Carbohydrate content of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) from 79.63g to 85.2g in SBY, 56.6g to 74.4g in SFT, 63.3g to 74.2g in SFM, 60.0g to 74.6g in SPM and 70.4g to 85.2g in SSM.
- Protein content of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) from 2.8g to 3.8g in SBY, 2.6g to 3.6g in SFT, 4.5g to 5.4g in SFM, 2.7g to 5.7g in SPM and 3.6g to 4.2g in SSM.
- Fat content of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) from 2.6g to 4.0g in SBY, 2.1g to 3.8g in SFT, 2.3g to 3.1g in SFM, 2.7g to 4.7g in SPM and 2.0g to 3.4g in SSM.
- Fibre content of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) from 3.5g to 4.7g in SBY, 1.5g to 2.1g in SFT, 1.3g to 3.6g in SFM, 1.4g to 5.6g in SPM and 1.5g to 2.7g in SSM.
- Calcium content of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) from 63.1mg to 68.2mg in SBY, 47.8mg to 50.7mg in SFT, 125.4mg to 151.1mg in SFM, 62.4mg to 68.2mg in SPM and 60.8 to 65.4mg in SSM.
- Iron content of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) from 3.5mg to 4.1mg in SBY, 1.8mg to 3.5mg in SFT, 2.1mg to 3.4mg in SFM, 3.6mg to 8.9mg in SPM and 1.8mg to 4.4mg in SSM.
- Vitamin C content of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) from 3.3mg to 4.5mg in SBY, 4.3g to 4.9mg in SFT, 3.2 mg to 4.0mg in SFM, 3.2mg to 4.2mg in SPM, 3.2mg to 4.2 mg in SSM.
- Beta-carotene content of the Oriental sweet potato millet bars increased significantly ($p < 0.05$) from 20.2 μg to 180.4 μg in SBY, 14.8 μg to 174.7 μg in SFT, 17.5 μg to 140.5 μg in SFM, 56.41 μg to 210.6 μg in SPM and 21.56 μg to 190.7 μg in SSM. The microbial analysis of the Oriental and Hannah sweet potato millet bars were evaluated at day 0, day 15 and day 30. From the analysis it is evident that the total plate count in day 0 was 0cfu/g for all the products. The total plate count is similar among the Oriental and Hannah sweet potato flour incorporated millet bars. On the 15th day the maximum total plate count was observed in SFM with a value of 8.2×10^5 cfu/g followed by SBY, SPM, SFT and SSM with values of 7.2×10^5 cfu/g, 7.1×10^5 cfu/g, 5.2×10^5 cfu/g and 5.1×10^5 cfu/g respectively. On the 30th day the maximum total plate count was observed in SFM with a value of 16.3×10^5 cfu/g

followed by SBY, SPM, SFT and SSM with values of 15.4×10^5 cfu/g, 15.3×10^5 cfu/g, 13.3×10^5 cfu/g and 13.2×10^5 cfu/g respectively on the 30th day.

- All the oriental and Hannah sweet flour incorporated millet bars had positive value and were lighter in colour with higher L values. All the oriental and Hannah sweet flour incorporated millet bars had the positive *a* value and were therefore slightly red. The *b* values were positive and therefore were slightly yellow. Since the samples were coated with dark chocolate the coated samples had lower *b* values.
- In comparison between the oriental and Hannah sweet potato flour incorporated millet bars, the hardness and adhesiveness values of Oriental sweet flour incorporated millet bars were higher. Among the Oriental sweet potato flour incorporated millet bars, the hardness values were observed to be high in the order of SPM, SBY, SSM, SFT and SFM. The adhesiveness values were observed to be high in the order of SFT, SFM, SSM, SPM and SBY. Among the Hannah sweet potato flour incorporated millet bars, the hardness Values were observed to be high in the order of SSM, SFT, SPM, SBY and SFM. The adhesiveness values were observed to be high in the order of SPM, SSM, SFM, SFT and SBY.
- In the Oriental sweet potato flour incorporated millet bars which was packed in LDPE laminated stand up paper pouches, the SBY has a predicted shelf life of 2.57 months, the SFT has a predicted shelf life of 2.94 months, the SFM has a predicted shelf life of 1.10 months, the SPM has a predicted shelf life of 2.57 months and SSM has a predicted shelf life of 2.94 months.
- It can be concluded that the in the hannah sweet potato flour incorporated millet bars which was packed in LDPE laminated stand up paper pouches, the SBY has a predicted shelf life of 2.20 months, the SFT has a predicted shelf life of 2.94 months, the SFM has a predicted shelf life of 2.20 months, the SPM has a predicted shelf life of 2.57 months and SSM has a predicted shelf life of 2.94 months.

Recommendations for further study

- 1.Trace elements like zinc, magnesium and potassium content of Oriental and Hannah sweet potato flour and Oriental and Hannah sweet potato flour incorporated millet bars can be analyzed.
- 2.Antioxidant assay of the Oriental and Hannah sweet potato flour incorporated millet bars can be analysed .
- 3.In vitro and In vivo bioavailability of the Oriental and Hannah sweet potato flour incorporated millet bars can be analysed .

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Appendices

APPENDIX I

ETHICAL CLEARANCE CERTIFICATE

INSTITUTIONAL HUMAN ETHICS COMMITTEE



Avinashilingam

Institute for Home Science and Higher Education for Women
(Deemed to be University under Category 'A' by MHRD, Estd. u/s 3
of UGC Act 1956) Re-accredited with 'A++' Grade by NAAC.
Recognised by UGC Under Section 12 B
Coimbatore-641 043, Tamil Nadu, India

26th February 2022

Chairman

Dr. Sudha Ramalingam
Director-Research & Innovation,
Professor-Community Medicine,
PSG Institute of Medical Sciences
& Research, Coimbatore

Member Secretary

Dr.S.Uma Mageshwari
Professor and Head,
Department of Food Service
Management & Dietetics

Members

Mr.K.Arunmoli (Legal Expert)
Dr.Subhashini K. Sripathi
Dr.A.Saraswathy (Medical Officer)
Ms.D.Kavitha
Dr.A.R.Sudamani Ramasamy
Dr.G.Victoria Naomi
Dr. Judith Justin
Dr.AnithaSubash

To
Ms.Abinaya.G.P
Department of Food Science and Nutrition
Avinashilingam Institute for Home Science and
Higher Education for Women
Coimbatore – 641 043

Dear Abinaya.G.P,

Ref: Your proposal No. IHEC/21-22/FSN-01 entitled
“Formulation of Beta Carotene and Fibre Rich Nutritious Bar Using
Sweet Potato (*Ipomoea batatas*) and Millets” submitted for approval
of IHEC on 23.11.2021.

The Institutional Human Ethics Committee of our University
hereby grants approval to your research proposal No. IHEC/21-22/
FSN-01 entitled “Formulation of Beta Carotene and Fibre Rich
Nutritious Bar Using Sweet Potato (*Ipomoea batatas*) and Millets”
submitted by you. The Approval number for the same is
AUW/IHEC/ FSN-21-22/XPD-01.

We wish you all the best in your research endeavours.

Regards,

S. Uma Mageshwari
Dr.S.Uma Mageshwari
Member Secretary



APPENDIX II
SCORE CARD FOR SENSORY EVALUATION

Name of the product: _____ **DATE:** _____

Instructions:

Taste the samples and check how much you like or dislike each one. Use the appropriate scale to show your attitude by checking the point that best describes your feelings about the sample. Please give a reason for this attitude. Remember you are the only one who can tell what you like. An honest expression of your personal feelings will help us.

Quality aspects	Standard	Variations		
		I	II	III
Appearance				
Colour				
Flavour				
Taste				
Texture				
Overall acceptability				

9-POINT HEDONIC SCALE	
9	Like extremely
8	Like very much
7	Like moderately
L	Like slightly
5	Neither Like nor Dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

APPENDIX III

PROCEDURE FOR NUTRIENT ANALYSIS

1. Determination of ash content:

Total ash content was determined using the standard protocols given by Manual Methods (AOAC). The clean crucible was kept in a muffle furnace at 400°C for half an hour, followed by cooling in a desiccator. Weight of the empty crucible was noted. Thereafter, 5 g of the sample was accurately weighed and placed in a tarred crucible, which was previously ignited, cooled, and weighed. The crucible with the sample was heated over bunsen burner till the sample got charred completely and later transferred to muffle furnace maintained at 650±10°C incinerated for 3 hours until free from carbon and it was cooled in a dessicator and weighed.

$$\text{Ash content (g/ 100g sample)} = \frac{\text{Weight of the ash}}{\text{Weight of the sample}} \times 100$$

2. Estimation of Total Energy Content

The energy value of foods was determined by using bomb calorimeter. One gram of the sample was taken and made into pellets with the aid of a pellet press, which consists of a mold into which the sample is placed and a pestle which is then pushed into the mold, crushing the sample material into a compact pellet. The pellet is then placed in the sample holder of the crucible and a 10 cm length of fuse wire and a length of cotton thread is tied onto the filament, and its ends placed into the crucible so that it will act as a fuse. The calorimeter bucket was carefully filled with distilled water and the bomb was transferred into the bucket. Through the valves the air is removed and oxygen is filled at 20 atm. It was kept inside the calorimeter vessel which contain 2000 g of water. Electrodes are fixed and the calorimeter is closed. The thermocouple was put in place in the top of the calorimeter. In the digital bomb calorimeter, the start button and stirrer is pressed. The change in temperature of the bomb is displayed in calorimeter. The difference in initial and final temperature was noted and calculation was carried out.

3. Estimation of Carbohydrate: (AOAC,1990)

100 mg of the sample was weighed into a boiling tube. The sample was hydrolysed by keeping 0 in a boiling water bath for three hours with 5 mL of 2.5 N HCl and it was cooled at room temperature. Neutralise it with solid sodium carbonate until the effervescence ceases. The volume was made upto 100 mL and centrifuged. The supernatant was collected and 0.5 and 1ml aliquots were taken for analysis. Prepare the standards by taking 0, 0.2, 0.4, 0.6, 0.8 and 1 mL of the working standard. '0' serves as blank. Make up the volume to 1 mL in all the tubes including the sample tubes by adding distilled water. Then add 4 mL of anthrone reagent. Heat for eight minutes in a boiling water bath. Cool rapidly and read the green to dark green colour at 630 nm. The analyses were performed in triplicates.

4. Estimation of Protein (AOAC, 1990)

Determination of protein content was carried out by micro kjeldhal method which consists of wet digestion (digestion flask), distillation (distillation chamber) and titration. The protein content was determined by weighing 0.2g of sample and transfer to a 250 ml Kjeldahl flask, care to see that no portion of the sample clings to the neck of the flask. To this 1 to 2 g of catalyst mixture (potassium sulphate 100 g and copper sulphate 20 g) and 10 ml of concentrated H₂SO₄ was added. Flask was placed on the stand in the digestion chamber and continue the process of digestion until the colour of the digest is pale green. The digestion mixture was cooled by adding 30 ml of water. After digestion, distillation was carried out by using 40% NaOH and 20% boric acid using methyl orange as an indicator and titrated against 0.1 N H₂SO₄. The protein content was calculated as follows:

$$\% \text{Nitrogen} = \frac{14.01 \times \text{ml titrate value of sample} \times N \text{ of H}_2\text{SO}_4 \times 100}{\text{Weight of the sample (g)} \times 1000}$$

Protein content was obtained by converting nitrogen to protein by using conversion factor of 6.25

Protein (%) = 6.25 x Nitrogen (%)

5. Estimation of Fat content (AOAC, 1990)

Crude fat was estimated by continuous soxhlet extraction technique (Socs plus , SCS 6 , Pelican equipment , Chennai , India) using petroleum ether (40-60°C B.P.) as a solvent. Finely powdered sample was placed in fat extraction thimble and placed in a clean, dry pre-weighed beaker to which 80 ml petroleum ether was added. This beaker was then placed in the soxhlet apparatus for the extraction of fat for 2-3 hours. After extraction, the beaker was removed and kept in a hot air oven (100°C) to evaporate traces of solvent. It was then transferred to desiccator, cooled, and weighed. The difference between the weight of the beaker before and after gives the quantity of crude fat extracted from the unknown amount of the sample. The result was expressed as a percentage on a dry weight basis. The analysis were performed in triplicates.

6. Estimation of Crude Fibre (AOAC, 1990)

2g of the sample was weighed in a 500ml conical flask. 200ml of 0.255N sulphuric acid was added and heated gently on a hot plate and boiled for exactly 30 minutes. The mixture was filtered in another conical flask through a muslin cloth over a funnel. The residue on the cloth was washed with 200-300ml of hot water until it was free from acid. The material was transferred from the cloth to the same beaker. 200ml of 0.313N sodium hydroxide was added and was boiled exactly for 30 minutes. The mixture was filtered through the same cloth through a funnel. The residue was washed with 200-300ml of hot water until it was free from alkali. The residue was transferred to a crucible and dried overnight at 80-100°C and weighed. The crucible was heated in a muffle furnace at 600°C for 2-3 hours. Cooled and weighed again. The difference in the weight represents the weight of the fibre.

$$\text{Crude fibre (g/100g sample)} = \frac{\text{Weight of the crucible with contents before ashing} - \text{Weight of the crucible with contents after ashing}}{\text{Sample weight of the sample (g)}}$$

7. Estimation of Beta Carotene

Pigment extraction for β-carotene analysis

This was carried out according to the method of the Association of Official Analytical Chemists (AOAC, 1980). In to a conical flask containing 50ml of 95% ethanol, 10g of the macerated sample was placed and maintained at a temperature of 70-80°C in a water bath for 20 minutes with periodic shaking. The supernatant was decanted, allowed to cool and its volume was measured by means of a measuring cylinder and recorded as initial volume. The ethanol concentration of the mixture was brought to 85% by adding 15ml of distilled water and it was further cooled in a container of ice water for about 5 minutes. The mixture was transferred in to a separating funnel and 25ml of petroleum ether (pet-ether) was added and the cooled ethanol was poured over it. The funnel was swirled gently to obtain a homogenous mixture and it was later allowed to stand until two separate layers were obtained. The bottom layer was run off into a beaker while the top layer was collected in to a 250ml conical flask. The bottom layer was transferred in to the funnel and re-extracted with 10ml petroleum ether for 5-6 times until the extract became fairly yellow. The entire petroleum ether was collected in to 250ml conical flask and transferred in to separating funnel for re-extraction with 50ml of 80% ethanol. The final extract was measured and poured in to sample bottles for further analysis.

Measurement of absorbance

The absorbance of the extracts was measured using a spectrophotometer (model 22UV/VIS) at a wavelength of 436nm. A cuvette containing pet-ether (blank) was used to calibrate the spectrophotometer to zero point. Samples of each extract were placed in cuvettes and readings were taken when the figure in the

display window became steady. The operation was repeated 5-6 times for each sample and average readings were recorded.

8. Estimation of Calcium (AOAC, 1990)

Calcium was determined by using the procedure given by Association of Official Agricultural Chemists (AOAC). 5g of ignited sample was dissolved in hydrochloric acid and made up to 100 ml. 10 ml of the ash solution was pipetted out in a conical flask and 90 ml of distilled water was added to it. A few drops of methyl red indicator were added. It was made strongly alkaline by adding ammonia and kept for boiling. The solution was heated to a boiling point and 20ml of saturated ammonium oxalate was added and this was done by adding 10ml each time to ensure complete precipitation directly. When it was hot, a few drops of acetic acid was added to render the medium acidic. The precipitate was allowed to stand overnight. The next morning, it was filtered through Whatman No. 40 filter paper and the precipitate was washed first with ammonical water and then with hot water several times until it was free from chloride. To test it 5 ml of the washing was collected, in a test tube, and a drop of silver nitrate solution was added. The filter paper was collected in a flask by making a hole in the filter paper. To this 2 ml of 2N sulphuric acid was added. The solution was heated to 70°C and when still hot it was titrated against 0.01N KMnO_4 to a permanent pale pink colour. From the volume of potassium permanganate solution used up the milligrams of calcium present in 100g of the sample was calculated. The analyses were performed in triplicates.

9. Estimation of Iron

The iron content of the sample was analyzed using the protocol given by AOAC. When ashing has been completed 5 ml of concentrated HCL was added and made up to 100 ml with distilled water in a volumetric flask. The standard iron solution was taken (1-5 ml) corresponding to 10- 50 in a series of test tubes. 1 ml of 30 % sulphuric acid, 1 ml of potassium persulphate, and 1.5 ml of potassium thiocyanate were added to all the test tubes. This was made up to 10 ml with distilled water. A blank was prepared by adding the reagent except for the standard. It was allowed for 20 minutes for the color development and the intensity was at 530-540 nm filter in the colorimeter. The analyses were performed in triplicates.

10. Estimation of Vitamin C (AOAC, 1990)

5 g of the sample was weighed and soaked 4 % oxalic acid for 10 minutes, this was then ground in a mortar and transferred to centrifuge tube by adding more oxalic acid. The supernatant was transferred 100 ml standard flask repeat the extraction with oxalic acid 3-4 times. All the supernatant was collected in the same standard flask and this was finally made up to the mark with acid. The dye was taken in a micro burette and titrated against 5 ml of the extract in a beaker. The endpoint was the appearance of pink colour which persisted for 30 seconds; the titration was repeated to get a concordant value. The analyses were performed in triplicates.