Development of Fruit Bar Rich in Beta Carotene and Vitamin C

By

Shobana.K

(20PFN022)

Thesis submitted to

Avinashilingam Institute for Home Science and Higher Education for Women

Coimbatore – 641 043

In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Food Science and Nutrition

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Certified as a Bonafide Research Work

Signature of the Candidate

Signature of the Supervisor

Signature of Head of the Department

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INTRODUCTION

I. INTRODUCTION

Fruits provide energy, vitamins, minerals, and dietary fiber. Fruits are preserved using several techniques namely drying, freezing, canning, pickling, fermenting etc., Processed form of fruits generally include candies, dried fruits, pasteurized mash, concentrated pulp, nectar, jam, jelly, pickle, chutney, frozen fruit and fruit bars. When compared to other products, fruit bars are minimally processed, have good shelf life and does not require more ingredients. Fruit bar preparation includes variety of pulp, fresh or dried fruit, sugar, binders, and other minor ingredients. Nutrition bars are food items meant to be consumed in a quick sitting, or on the go (Manimegalai *et al.,* 2001). They contain a wide range of vital nutrients and vitamins, as well as sufficient protein and carbohydrates to keep the body functioning. Fruit bars are made up of real fruit or fruit juice. New trends in fruit bar processing include using gelled fruit matrices, dried gels or sponges, and extruders. Fruit bars are best made with pulpy fruits such as banana, mango, guava, pear, papaya, musambi, tomato, grapes, apple etc., Fruit bars are regarded hygienic because they are manufactured mechanically. They are attractively packaged and easily consumed. Fruit bars are beneficial to consumers, particularly children, due to their flavour, shelf life, and nutritional value.

Plants, algae, and photosynthetic bacteria contain carotenoids as pigments. These pigments are responsible for the vibrant yellow, red, and orange colours found in plants, vegetables, and fruits. Carotenoids in the diet are thought to have health benefits by lowering the risk of disease, particularly certain cancers and eye disease. Beta carotene act as antioxidant and reduce free radicals and it has the ability to convert into vitamin A. Lutein and zeaxanthin may be beneficial in the prevention of eye disease because they absorb harmful blue light that enters the eye. Large doses of beta-carotene were found to have a negative effect on the incidence of lung cancer in smokers and asbestos workers (Johnson, 2002). The sweet potato (*Ipomoea batatas*) is a tuber that grows underground. Sweet potatoes are nutritious, high-fiber, filling, and delicious vegetable that can be simmered, baked, steamed, or fried. It contains beta carotene, an antioxidant that is very effective in increasing vitamin A in the blood, especially in children. Sweet potato is the world's seventh most important food crop, contributing significantly to energy and phytochemical nutrition. Sweet potato is a dicotyledonous plant with tuberous root and

belongs to morning glory family, *convolvulaceae,* which is also known as bindweed and it originates in the tropical regions of America. Tender shoots and leaves of sweet potatoes are included in diet in the form of greens. Sweet potato is a root vegetable with sweet taste and mostly comprises of starch (Hair and Stephen, 2014).

China is the largest producer of sweet potato which yields 56% of total production (Ahn and Peter, 1993) in the world. There are various types of sweet potato which are available in different colours. Its importance among the world's major crops is widely recognised as an important food crop for humans and animals due to its desirable starch, sugar, protein, and vitamin content (Ozturk *et al.,* 2012). Sweet potato is also available in other colours such as white, cream, yellow, reddish, purple and deep purple (George *et al.,* 2019). They can be cooked, baked or steamed and can be made into a dish (Reid *et al.,* 2016) and can replace a whole meal. While comparing with orange, red, pink sweet potatoes, white and pale yellow varieties are high in moisture content and less in sweetness.

Ipomoea Batatas are called as *batata* in Argentina, Brazil, Columbia, Dominican Republic and Venezuela and as *camote* in Philipines, Mexico, Peru, Bolovia and Central America and also white pulp variety is known as *Maori,* (Yen, 1963) orange pulp as *Beauregard*, red pulp variety as *Owairaka.* Carotenoids in sweet potatoes might lower the risk for cancer. Sweet potatoes can lower the LDL "bad" cholesterol, which may in turn lower the odds of heart problems (Stephanie Booth, 2021). The DNA sequence of sweet potato carries the genome of *Rhizobium* known as *Agrobacterium* earlier (Kyndt and Tina, 2015). Sweet potatoes are entirely different from normal potatoes. They are entirely from different families, (Perry, 2002) provides discrete amount of nutrients, affect blood sugar in divergent manner. Sweet potatoes are used to remove skin blemishes, fights aging by reducing age spots and wrinkles and helps to reduce cracked heels, fibrocystic breasts, sallow skin, (Burtenshaw, 2009) puffy eyes, dark circles, gout, hypokalemia etc., by combining with other herbs, it helps to prevent cancer and colic diseases.

Sweet potatoes are a first-rate supply of fiber, in particular while devouring the skin. Fiber is essential in digestive health, stopping constipation and critical diseases, inclusive of colon cancer. One medium sweet potato has six grams of nutritional fiber.

They additionally incorporate resistant starch, a sort of starch that performs function in feeding the body's "good" bacteria. Fiber in sweet potato helps to keep up healthy body weight by improving satiety. Additionally, it draws water to the large intestine, lubricating the viscous movements and making them easier to pass through membranes.

More than 90 % is produced in Asia, with China accounting for 85 %. While sweet potato production and planted area in Africa nearly doubled over the last three decades, they still account for less than 5% and 15% of developing-country totals, respectively (FAO 2020). Fresh sweet potatoes are chipped, dried, and ground into flour, which is then combined with wheat flour and baked into chapattis (bread). Some Indian communities convert between 15 and 20% of sweet potato harvest into pickles and snack chips. In India, a portion of the tuber harvest is used as cattle fodder. Sweet potato varieties additionally contain magnesium and dietary fibers that profit stable blood sugar (Lebot and Vincent, 2020).

Sweet potato production in India was 1,156,000 metric tons in 2019. Sweet potatoes were grown on an estimated 110,000.00 hectares in the country. The portion of fruits and vegetables that is not edible after processing (waste), including peels, pods, seeds, skins, etc., accounts for about 10-60% of the total weight of fresh produce. Sweet potato waste was about 7% of the entire crop in 2011 (FAO, 2020). Byproducts from the processing of the sweet potato into starch, alcoholic beverages, ethanol, flour, purees, and other commodities currently have very little use and contribute to the waste going into land and water bodies. In 2011, the FAO food balance sheets estimated that 53% of the world's sweet potato production (102,530 thousand metric tons) was used as food or seed, 40% as feed, and 7% was wasted.

The apple is a Rosaceae family pome fruit, an accessory fruit formed by enlargement of the flower receptacle. Apple is an important part of the diet and an excellent source of nutrients and health-promoting bioactive compounds as it is available all year (Boyer and Liu, 2004). It also contains antioxidants like vitamin E which helps to protect the cells by reducing free radicals, vitamin B1 in apple supports growth and development and vitamin B6 is needed for protein metabolism (Feng *et al.,* 2021). Malic acid in apples accounts for about 90% of total organic acid content. Soluble fiber in apples helps to reduce the blood cholesterol levels. Aside from market

trends and needs, the apple is grown on all continents, ensuring a good supply chain worldwide and ensuring the good potential use for developing phenolic compounds into a bio refinery concept (Silva *et al.,* 2021).Apple is one of the most popular fruits in the world, with well-known nutritional properties.

Apart from being consumed fresh, it is the raw material for several food products, the production of which generates a substantial amount of by-products. Apple consumption may have a prebiotic effect, which could be an important mechanism for lowering CVD risk markers. Polyphenols in apples, particularly complex polyphenols and dietary fiber, can influence enterohepatic circulation by binding bile acids in the intestine (Koutsos *et al., 2015*). Because of their high fiber and water content, apples are particularly filling. The polyphenols may have anti-obesity properties as well. Flavonoids in apples can help prevent heart disease by lowering blood pressure, lowering LDL cholesterol oxidation, and lowering atherosclerosis, or the buildup of plaque in arteries (Parmenter *et al.,* 2020). Apple fiber improves gut-friendly bacteria, and hence thought to help protect against chronic diseases. Apples contain antioxidant and anti-inflammatory compounds that aid in the regulation of immune responses and the prevention of asthma. Apples contain quercetin, which protect brain from oxidative stress. Preserved fruit, candied fruit, fruit puree, jelly, jam, fruit skin, canned apples, apple wine, cider, champagne, apple juice concentrate, vinegar, apple pectin, apple powder are the processed form of apples.

Dates are excellent source of macro and micro nutrients. Dates are very sweet and accounts for 50–88% of the total weight depending on cultivar, stage of ripening, and water content. Sugars account for roughly two-thirds of date flesh (Mahvish and Zahra, 2020). The remaining dates weight consists of protein, fat, crude fiber, minerals, various vitamins (particularly vitamin B), tannins, and a variety of other components. Dates have a high nutritional value and can help humans meet their nutritional requirements. Fresh dates contain approximately 1570 calories per kilogram, whereas dry dates contain more than 3000 calories per kilogram. Dates are primarily composed of carbohydrates, which include reducing sugars such as glucose and fructose, as well as non-reducing sugars such as sucrose and trace amounts of polysaccharides such as cellulose and starch. According to Hegazi, (2005) polysaccharides found in date flesh

and seeds include xylose, arabinose, glucose, and galactose. Dates fruit is beneficial in terms of glycemic control among diabetic patients; therefore, physicians may not need to limit its use among diabetic patients. Dates contain a variety of vitamins and minerals, as well as fiber and antioxidants. However, because they are a dried fruit, they are high in calories.

Fresh dates are made up of soft, easily digestible flesh as well as simple sugars. When consumed, they instantly replenish energy and revitalize the body. Dates are chemically composed of 81–88 % sugars, primarily fructose, glucose, and sucrose, 5–8.5 % dietary fiber, and a trace of protein, fat, ash, and high levels of phenols (Elleuch *et al.,* 2008). Dates are high in fiber, which may help prevent constipation and control blood sugar levels (Rahmani *et al.,* 2014). They also contain a variety of antioxidants that may aid in the prevention of certain chronic illnesses such as heart disease, cancer, Alzheimer's disease, and diabetes (Essa *et al.,* 2016). Dates may be beneficial in reducing inflammation and preventing plaque formation in the brain. When consumed during the last few weeks of pregnancy, dates may promote and ease natural labour in pregnant women (Kordi *et al.,* 2017). Because of their sweet taste, nutrients, fiber, and antioxidants, dates are a healthy substitute for white sugar in recipes. Dates paste, dates powder, dates syrup, chopped dates, dark date syrup, golden date syrup, dates sugar are some of the processed dates products.

A guava fruit usually measures between 4 and 12 cm long and is round or oval depending on the species. It has a distinctive, characteristic scent, similar to lemon rind but less sharp. In 2019, 55 million tons of guavas were produced worldwide, with India producing 45% of the total (Judd *et al.,* 2002). Botanically, guavas are berries.Guava is widely consumed and rich in phytochemicals with medicinal value. Guava is frequently included among super fruits due to its high nutritional value. Consumption of ripe guava fruit with peel reduced BMI and blood pressure ($p<0.05$), whereas fasting blood glucose (FPG), total cholesterol, and triglycerides were significantly increased ($p<0.05$). Guava extract may help people with diabetes or those at risk of developing diabetes to control their blood sugar levels. Guava fruit extract may benefit heart health by lowering blood pressure, lowering bad cholesterol, and increasing good cholesterol, prevent or alleviate diarrhoea and constipation. Guavas are high in fiber and low in calories, so they

improve digestion and lose weight. Guava's high antioxidant content aid in the prevention of cancer cell development and growth (Ryu *et al.,* 2012). Guavas are one of the highest vitamin C-containing foods. It is critical to maintain adequate levels of this vitamin in order to protect against illness and infection (Shaik *et al.,* 2013). Guavas contain antioxidants and vitamins that can help slow the ageing of skin, and guava leaf extract may help treat acne (Qadan *et al.,* 2005).

This humble fruit is extremely high in vitamin C, lycopene, and antioxidants that are good for the skin. Guavas are also high in manganese, which aids the body's absorption of other important nutrients from the food consumed. Guava benefits are attributed to the presence of folate, a mineral that aids in fertility promotion. Guava has potassium content also aids in blood pressure regulation. In fact, a banana and a guava have nearly the same potassium content. Because it contains approximately 80% water, it aids in keeping the skin hydrated (Teixeira, 2020). The vitamin C content of guava fruit is four times that of oranges. Vitamin C boosts immunity and protects body from common infections and pathogens. It also keeps the eyes healthy. Because it is high in lycopene, guava fruit has been shown to be effective in lowering the risk of prostate cancer and inhibiting the growth of breast cancer cells. Guavas help to prevent the development of diabetes due to their high fiber content and low glycemic index. While the low glycemic index prevents a sudden spike in sugar levels, the fiber content keeps sugar levels well-regulated (Adamska *et al.,* 2018). Guava pulp is an excellent raw material to make numerous other guava products such as juice, blended RTS drinks, wine, jam, toffee, cheese, ice cream topping, and nectar (Usha *et al.,* 2017).

Banana is one of the world's most popular fruits and the fourth most important crop produced on a global scale. Banana pulp, which is the edible part of the fruit, is high in nutrients. Banana pulp has its use as a food additive to the extraction and isolation of numerous health-beneficial components such as different types of starch, cellulose, and bioactive compounds (Singh *et al.,* 2014).Because of its high levels of vitamin A activity and sugars, the nendran banana is a good potential fruit that could be widely produced as a nutritional and energy food resource. According to Food and Agriculture Organization (FAO) statistics 2020, Asia is the world's largest banana producer, accounting for 54.4 % of global banana production. Bioactive constituents in

bananas invariably confer a number of potential medicinal values against oxidative damage, which aids in the prevention of genetic damage or DNA compromise, the improvement of innate immune competence, neurological functioning, and the reduction of the risk of cardiovascular disorder (Oyeyinka, 2020). One banana has about 112 calories and is almost entirely made up of water and carbohydrates. They contain very little protein and no fat. Bananas contain a lot of soluble fiber. Soluble fiber dissolves in liquid to form a gel during digestion. It is also responsible for the sponge-like texture of bananas.

Despite their higher carbohydrate content, bananas do not cause significant blood sugar spikes in healthy people (Lin *et al.,* 2015). People with diabetes can eat bananas, it is not recommended that they consume a large amount in one sitting. Fiber in the diet has been linked to a variety of health benefits, including improved digestion. One medium banana contains about 3 g of fiber. Pectin, a fiber found in both ripe and unripe bananas, aid in constipation prevention and stool softening. Bananas are a convenient source of potassium, with a medium-sized banana (126 g) providing 10% of the Daily value (Mun *et al.,* 2019). Bananas have 8% of the daily value for magnesium, a mineral important for heart health. Magnesium deficiency may be associated with an increased risk of heart disease, high blood pressure, and high fat levels in the blood. Bananas contain a variety of powerful antioxidants, such as flavonoids and amines. These antioxidants have been linked to a variety of health benefits, including a lower risk of heart disease and degenerative diseases. They aid in the prevention of free radical-caused oxidative damage to the cells. Without antioxidants, free radicals can accumulate over time and cause harm if the level in the body became high enough (Wang *et al.,* 2014).

Banana’s soluble fiber may help to stay full by adding bulk to digestive system slowing digestion. Bananas are also relatively low in calories for their size. Bananas' low calorie and high fiber content make them a more filling snack than other foods such as processed or sugary boxed snacks. Bananas have been renamed as the "Perfect Food for Athletes." This is largely due to their high concentration of easily digestible carbohydrates as well as the minerals potassium and magnesium, both of which act as electrolytes. Resupplying the body with potassium and magnesium after sweating, by

eating a banana, may help to reduce exercise-induced muscle cramps and soreness (Baker *et al.,* 2020).Bananas are not only extremely healthy, but they are also one of the most convenient snack foods available. They go well with yoghurt, cereal, and smoothies, and they are delicious as a topping on whole grain toast with peanut butter. Bananas are not only extremely healthy, but they are also one of the most convenient snack foods available. Banana puree, chips, powder, wine, beer, preserve, jam, jelly, concentrated pulp, fruit bar are processed banana products. The fruits for the present study are selected based on the literature survey which has health potentials. Only very few Indian studies are available in developing fruit bars in combination with sweet potato and keeping this in mind, an attempt was made in the present study, entitled with the following objectives to:

- development and standardization of fruit bars using sweet potato and selected fruits
- carry out sensory evaluation of the developed fruit bars
- analyze the major nutrients and physiochemical properties of the fruit bars

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The Review of Literature pertaining to the study **"Development of Fruit Bar Rich in Beta Carotene and Vitamin C"** is presented under the following sub headings:

A. Nutritional importance of fruit bars

B. Sweet potato as a source of beta carotene and its nutritional benefits

C. Vitamin C rich fruits and human health

D. Chemical and nutritional changes in fruits on processing

A. Nutritional importance of fruit bars

Fruits are rich in vitamins, minerals, electrolytes, fiber, phytochemicals, and antioxidants (Slavin and Lloyd, 2012). Most of the fruits are seasonal and available all year round. India is the world's 2nd largest producer of fruits, but 20% of fruits produced were not utilized because of post-harvest losses. New products are developed from fruits to make them available at any season. Drying of fruits in sunlight had been practiced for years to preserve fruits and now sun drying is replaced by electric dehydrating machine as it takes minutes to complete the process. Canning of fruits is a popular method of fruit preservation in which fruits are preserved in sterilized cans with a vacuum seal. Preparation of pickles, jam and jellies are other methods of fruit preservation which undergoes several processes and addition of preservatives. Postharvest application of p-Anisaldehyde proved to be a credible method for controlling postharvest decay and preserving the quality of harvested dragon fruit by increasing the antioxidant potential of the ascorbic acid and glutathione cycle and activating an antioxidative defense system to reduce Reactive Oxygen Species (ROS) accumulation (Xu *et al.,* 2021).

Due to its efficiency and low impact on juice quality and characteristics, hurdle technology could be a useful method for the preservation of fruit juices, though all processing parameters still need to be optimized (Putnik *et al.,* 2020). Exogenous application of melatonin can improve the antioxidant and defense systems of guava fruit, thereby preserving its quality and increasing its resistance to disease (Fan *et al.,* 2022). Fruit bars are a traditional way of modifying fruits which are dehydrated confectionery

products that are often included as snacks or desserts and also called as fruit slabs or fruit leather (Giacalone *et al.,* 2019). Compared to toffees and chocolates, fruit bars are highly nutritious, and are prepared from fresh fruits with rich pulp fruits like mango, papaya, banana, guava, pineapple, apple, passion fruit, musambi etc., They are perfect snacks and occupy only small space in bags, easy to carry while travelling as well as they also possess a greater shelf life when compared to fresh fruits. Fruit bars can be prepared using simple methods without any need for special equipment and can be easily incorporated into the diet of an individual (Tontul *et al.,* 2019). There are lots of benefits in preserved fruit products. They are available in all seasons, increases the fruit supply as there is less wastage, possess longer shelf life than normal fruits and it also decreases the dietary inadequacies. Fruit bars can be a healthy, convenient, and natural alternative to high-salt, high-sugar, and high-fat foods.

Fruit leather was developed with mango and natal plum fruit in 2:1 ratio which increases the phytochemical properties and dietary intake of phytochemicals specifically in school children and adolescents (Mphaphuli *et al.,* 2020). During storage, water activity of the fruit bar plays a vital role in color change. At 52.3% relative humidity strawberry leather undergoes anthocyanin degradation that was found to be correlated with reduction of red chromatic parameter (Raquel *et al.,* 2022). Fruit bar has an attractive colour, flavour, and are available in different shapes, provides nutrients equal to half of the daily fruit intake, which is highly stable and convenient (Simao *et al.,* 2020). For drying small quantities of fruits, solar cabinet dryers were preferred whereas simple sun drying is unhygienic lengthy process (Diamante, 2020). Fruit bars are prepared with or without the addition of other ingredients but later are sticky to teeth and fingers. Adding gums, starches, pectin and sugars helps to overcome stickiness (Harshini and Manish, 2020).

Fruit bars were prepared by extracting the pulp and mixing with sugar or jaggery in a ratio ranging from 1:2 to 1:4 and are dried in sun by spreading it over the bamboo mats one by one after the first one was dried (Sathiamoorthy, 2019). Dried fruit bars were cut into identically sized bars and wrapped in cellophane sheets to prevent the loss of nutrients and moisture (Chavan, 2016). Mathur *et al.* (1972) prepared fruit bar by combining dual fruits like mango and pineapple, papaya and guava, banana and jamun.

Total Soluble Solids (TSS) were increased up to 30°C and 1.5% of pectin and liquid glucose were added to the fruit pulp followed by addition of 0.1% potassium meta bisulphite and the pH was brought to 4.2 and moisture content was maintained at 12-16%. Mango-pineapple, jamun-banana combinations of fruit bars resulted in good texture, flavour and stability was prepared by drying at 30-80°C for about 24 hours (Janette, 2014). The microbial content of the fruit bar was zero at initial days and after 180 days, microbial content rose up to 4×10^5cfu/g and it varied according to the packaging material (Bhatt and Jha, 2015).

Moisture content plays an important role in processing, fruit bar becomes hard and difficult to chew if moisture content falls below 7%. Water activity was maintained at the safe level during storage period and no major fluctuations were reported (Shahid *et al.,* 2020). There was no sufficient resource on fruit bar manufacturing from clarified fruit juices. Texture of fruit bars become hard with storage period, because of the difference in the composition of pulp and ratio to soluble to insoluble solids (Laxman, 2017). Iron fortified fruit bars were developed by the addition of dried fruits, dried milk powder, quince fruit paste, and barley flour (Syeda *et al.,* 2020). Methods were modified for the pulp preparation and drying to enhance the taste and avoid contamination of microbes (Rameswar, 1979). The researchers processed fruits like mango, banana, guava, papaya for preparation of fruit bars. Mango fruit bar had bright colour, sweet taste and fine texture and successfully commercialized (Huang *et al.,* 2005).

Fruit bars were prepared using tropical or temperate or subtropical fruits (Pasupuleti, 2002). In apple – black currant fruit bar, drying temperature was reduced to maintain water activity closer to 0.60, thereby increasing moisture content resulting in higher product yield (Busch *et al.,* 2013). Fruit bars with enhanced sensory qualities and shelf life was developed by extraction of pulp using conventional methods and treating with enzymes at minimum concentration (Myers *et al.,* 2009). Papaya and banana pulp were taken and fruit bars were prepared in different variations with 15% of soymilk which contains more proteins and fats when compared to fruit bars without soymilk (Ram and Chandrika, 2004).

Apart from positive results, undesirable hard bar of papaya and banana was obtained at ratio of 7:3, soft bar with loose texture obtained at 1.5:1.5:7 while combining

papaya, soymilk and banana and finally the proportion of accepted fruit bar was 6.5:0.5:3. During preparation of fruit bar, 350ppm of potassium meta-bi sulphite was added and mixture is transferred into aluminium trays usually greased with glycerine (Ranganna, 2016). Agave fructans helps to improve the probiotic potential of the fruit bar and lower the hardness and hence replaced for sugars in fruit bars. Increase in the sugar content during storage of fruit bar may be due to polysaccharide hydrolysis (Kumar, 2012). Changes in sensory characteristics and chemical composition of fruit bar were observed when different packaging materials was used (Phimpharian *et al.,* 2011). Studies have reported that fruit bars developed in papaya and banana were packed in two different packages, polyethylene bag and butter paper overwrapped with metallic paper. Rise in reducing sugar, TSS, total sugars, acidity and fall in moisture content, calcium, ascorbic acid and beta carotene was dominant in fruit bars packed with polyethylene bags while comparing with butter paper wrapped with metallic paper (Chavan *et al.,* 2019).

By reducing the moisture content, 2.5kg of fruit bar was prepared from 10kg of fruit pulp (Indian Council of Agricultural Research, 2021). Browning was observed in fruit bars after few hours of preparation which was overcome by addition of citric acid or blanching (Lee and Hsieh*,* 2008)**.** Drying rate of fruit bars can be reduced by the addition of cellulose, pectin and guar gum (Gujral and Brar, 2003). Methods of drying fruit bars include solar drying, cabinet drying, hot air drying, microwave oven drying, vacuum drying etc. Fruit bars were prepared not only from fresh fruits but also from leftover ripened fruits (Laxman *et al.,* 2017). Acceptability of fruit bars decreased after 90 days of storage in both room temperature and refrigerated temperature (Saranya *et al.,* 2017). Apple-apricot fruit bar was standardized by drying the sheet in steel trays instead of aluminium trays at 85°C with 5% relative humidity for about 6 hours. This method provides good quality product (Bains *et al.*, 1989). Acrylic trays used for drying, subjected to 60°C in hot air dryers were reported to reduce the moisture content to one third within 3 hours of time (Leiva *et al.*, 2009). Banana-pineapple-apple bar prepared in three variations, A (20:40:40), B (60:20:20), C (40:40:20) showed that variation A has higher moisture of 4.14%, variation B has high fiber of 12.47%, variation C has high carbohydrate content of 84.77% (Blessing *et al*., 2015).

B. Sweet potato as a source of beta carotene and its nutritional benefits

Sweet potatoes are rich in beta carotene which is the precursor of vitamin A. Scientific name of sweet potato is *Ipomoea batatas*. Study by Choong (2007) proves that 100g of sweet potato is enough to meet the daily requirement of vitamin A. Amylose and beta carotene content of sweet potato is affected by environmental factors (Laurie *et al.,* 2012). Fresh sweet potatoes are commonly preserved and processed into dried slices, flakes, and flour in many developing countries for use in a variety of formulated foods such as noodles, soups, beverages, bakery and confectionery products, and snacks (Yang and Gadi, 2008).Sweet potato is well suited to processing due to its high starch content and has become a potential resource for starch and starch-derived industrial products. Sweet potato is used to make a variety of products and ingredients, including flour, dried chips, juice, bread, noodles, candy, and pectin. Mapping of gene traits shows that 100g of sweet potato contains 13.83 mg of beta carotene (Nedunchezhiyan *et al.,* 2010). Bi parental mapping of quantitative trait loci on linkage group 3 and 12 increases the beta carotene content in sweet potato and decreases the starch content (Gemenet *et al*., 2020).Improved biochemical properties and antioxidant properties were observed in bio-fortified sweet potato which helps to fight food insecurity and micro nutrient deficiency (Oloniyo *et al.,* 2021).

Effect of broiler litter manure at rate of 0.5 t ha^{-1} treatment has highest beta carotene content (262.0 µg/g) and forms firm sweet potato with deep orange colour and also reduces water pollution with low cost farming activities (Gichuhi *et al.,* 2014). Cross between 'New Kawogo' × 'Beauregard' traits of sweet potato showed that beta carotene content decreases and the storage yield increases along with dry matter and starch content (Yada *et al.,* 2017). Shredding decreases the phenolic and antioxidant activity and pie cut improves quality by enhancing phenolic and antioxidant properties (Dovene *et al.,* 2019). Beta carotene in the sweet potato which is also known as pro vitamin A helps to prevent night blindness and other symptoms of vitamin A deficiency (Van *et al.,* 2000). Apart from carotenoids, sweet potatoes also possess bioactive compounds that include anthocyanins, phenolic acids, other flavonoids and vitamin C (Truong *et al.,* 2007). Out of all phytochemicals, flavonoids are specifically known for its anticancer and antioxidant properties as they evince strong superoxide-radical scavenging activity (Ren

et al., 2003). Vitamin A in sweet potatoes helps the body to build immune cells that foreclose infections and malady and have anti-tumor effects. The total concentration of carotenoids (provitamin A) in sweet potato varies significantly depending on plant part, genotype or phenotype, and food processing. In general, sweet potato is regarded as a high-quality source of provitamin A. Orange-fleshed sweet potatoes are the best source of β- carotene and total carotenoids, and certain varietals, such as Tomlins, Owori, Bechoff, Menya, and Westby, rank higher (20–364 g/g DW) than other recognised β-carotene sources, such as carrots (182.5–88.4 g/g DW) or mango (Escobar *et al.,* 2022).

Sweet potato was known to be the first example of naturally produced transgenic crop. The extracts of sweet potato in used in the preparation of black and purple dyes, production of ink, rubber and glue, starch and alcohol (Ember *et al.,* 2004).Biologically active carbohydrates, proteins, fatty acids, carotenoids, anthocyanins, conjugated phenolic acids, and minerals are found in various parts of the sweet potato (tubers, leaves, stems, and stalks). Sweet potatoes have distinct composition that contributes to numerous health benefits, including anti oxidative, hepato protective, anti inflammatory, antitumor, anti diabetic, antimicrobial, anti obesity, and anti aging properties (Wang *et al.,* 2016)**.**Sweet potato processing had no effect on antioxidant or enzyme activity, but it did cause significant changes in the colour of the juice. Ultrasound, as a processing technology, allows for the preservation or enhancement of the quality of sweet potato juice, and when combined with other treatments, it facilitates the development of new products (Rios *et al.,* 2021).

Sweet potato is 1900 times rich in vitamin A when compared to normal potato (Huang *et al.,* 2021). It is usually large in size and great source of beta carotene which is the precursor of vitamin A. Foods enhanced with naturally existing carotenes are examined, and Orange-Fleshed Sweet Potato (OFSP) stands out as being high in beta carotene, a provitamin A carotenoid. The amount of bio accessible beta carotene in the OFSP wheat breads, combined with altered starch digestion, emphasises their utility as novel functional food that could address vitamin A deficiency as well as glycemic problems, thereby improving human health (Mbogo *et al.,* 2021). Different varieties of sweet potato are rich in different types of phytochemicals, for example anthocyanin is rich in purple sweet potato and possesses antioxidant properties (Fan *et al.,* 2017).

Anthocyanin raises blood levels of children, very effectively due to the presence of beta carotene, which is enormously high in sweet potato.

100g of sweet potato usually contains 86 calories, 77% of water, 1.6 g of proteins, 20.1 g of carbohydrates, 4.2 g of sugar, 3 g of fiber and 0.1 g of fat (Roullier *et al.,* 2013). Root of sweet potato extract contains anthocyanins and flavonoids and posses anticancer activity against breast cancer cell lines. Myricetin, quercetin, and anthocyanin are the flavonoid compounds in sweet potato which inhibit the growth of breast cancer cells (Ghasemzadeh *et al.,* 2016). The natural bioactive compounds in sweet potato contain anticancer and antioxidant property and are most preferable in food. Composition of the bioactive compounds and level of antioxidant activity have to be proven useful in standardizing sweet potato for medical applications. Methyl Jasmonate (MeJA) treated sweet potatoes are another source that possess anticancer activity. MeJA has high potential for enhancing health benefits of sweet potato based functional food (Bari *et al.,* 2009).

Naomi *et al.* (2021) proved that sweet potato helps in treating hyperglycemic condition by signaling mechanism and is also capable of regulating dyslipidema. Bioactive substances with acidic characteristics, radical scavengers and phenotypic variability are found in abundance in sweet potato extract (Jang *et al.,* 2019). Korean pumpkin sweet potato (Ib2-AgNPs) had higher functional activity than Korean red skin sweet potato (Ib1-AgNPs), which could be attributed to the greater abundance of bioactive compounds present in Ib2 extract, also acted as reducing and capping agents in the synthesis of Ib2-AgNPs (Das *et al.,* 2019). Studies by Adda (2019) reported that sweet potato contains 53% of carbohydrates from starch, 32% of carbohydrates from simple sugars such as glucose, fructose, maltose and sucrose. Another study by Yadav *et al.* (2009) revealed that sweet potatoes consist of 80% of rapidly digested starch, 11% of resistant starch, and 9% of soluble digested starch. It had high glycemic index ranging between 44-96, hence not recommended in large amounts in a single meal for people with type 2 diabetes.

Sweet potato is a versatile vegetable that can be used to replace medication which is effective in the treatment of hyperglycemia, and its activity has been found to be greater than that of diabinese, a commonly used diabetes drug (*Shih et al., 2020).*

Within 8 weeks of consuming sweet potato of about 5% of daily diet, pancreatic cell function readily increased, with reduced lipid levels, diminishing insulin resistance, and glycemic index is lowered *(*He *et al.,* 2020). As there haven't been many clinical trials on this extract, evidence is still lacking. There is no clinical data on the use of sweet potato in the treatment of dyslipidemia, but a Cochrane review indicates that 4 g/day is safe for up to 5 months of hyperglycemic treatment (Drapal *et al.,* 2019).

Caffeic acid derivatives, anthocyanosides, flavonoids, and oligosaccharides typically extracted from *Ipomeae batatas* are said to be effective anti-diabetic agents (Lee *et al.,* 2016). Three types of sweet potato with different flesh colours (yellow, orange, and purple) showed a significant difference in sweet potato primary metabolism. Secondary metabolism, including phenylpropanoids and carotenoids, was used to determine the metabolic diversity of storage roots. Short-term cold storage for 14 days promoted accumulation of sucrose, chlorogenic acid, and amino acids with no chilling injury development in sweet potato, had enhanced sweetness, antioxidant capacity, nutritional value with improved palatability without compromising freshness (Zhou *et al.,* 2021). Sweet potato extract has shown to reduce hyperinsulinemia (high insulin levels) by up to 50%, as well as to greatly lower insulin resistance and increase glucose tolerance (Anoma and Joseph, 2016).

Purple-fleshed sweet potato varieties, such as YS43, YZ7, and YY153, had higher total phenolics content, higher total antioxidant capacities, and also transcriptional anti proliferative activities against human liver carcinoma HepG2 cells than other varieties. However, no correlation was discovered among cytoplasmic antioxidant capacity and total phenolic content or skin colour of sweet potatoes (Hongnan *et al.,* 2019). Orange-fleshed sweet potato varieties are excess in beta-carotene, whereas purple-fleshed ones are rich in anthocyanin. These two vital antioxidants are thought to forestall chronic heart diseases and cancer (Teow *et al.,* 2007). Sweet potatoes work best in fighting inflammation. One sweet potato contains over half of suggested dietary intake of vitamin C and more than 1 / 4 of daily vitamin B6 and also contains vital levels of protein. Studies have reported that sweet potato contains 8.41% of sugar (Lai *et al.,* 2013). Contrastingly a study by Jessica Bruso (2018)

has reported that only 1% of sugar is present in sweet potato. These findings supported the studies suggesting that 4.2% of sugars are present in sweet potato (Shani, 2021).

Sweet potato contains 77-85% of insoluble fibers in forms of lignin, cellulose and hemicellulose which helps in improving the health of the gut, lowering the risk of diabetes and plays a vital role in incorporating macronutrients in the diet. Soluble fibers is present up to 15-23% and mostly consists of pectin and fill satiety so that food intake is reduced and also reduces the risk of diabetes by slowing down the digestion process. 80% of proteins in sweet potatoes are sporamins which is a unique type of protein synthesized by plants for the purpose of healing in case of physical damage (Govender *et al.,* 2019).Emerging health advantages of the orange flesh sweet potato are substantial, creating a fair lot of vital food-especially for populations in peril of deficiency disease (Kaspar *et al.,* 2013). The typical yield and space coverage of sweet potato is low compared to world context. Recent study revealed that sporamin may have antioxidant properties (Salelign *et al.,* 2021).

Despite the sweet taste, tweaking the eating regimen with sweet potatoes can progressively lessen LDL (Low Density Lipoprotein) level, which frequently results in clogging up of arteries and professionals agree with that slight intake of sweet potatoes can assist in enhancing heart health. Potassium facilitates in coping with the body's sodium level and wholesome stability of sodium can prevent the thickening of blood inside the arteries (Grace *et al.,* 2015). The proper balance of sodium in the body helps in preserving the blood vessels dilated thereby decreasing the cholesterol levels. To lessen the LDL levels, the National Lipid Association recommends consuming meals which can be excessive in soluble fiber. Sweet potato is a starchy vegetable and also high in fiber (Li *et al.,* 2015). When boiled, sweet potatoes are low on the Glycemic Index (GI), *i.e*. they do not increase blood sugar as fast as high-GI foods (Omoba *et al.,* 2020).

A research by Herawati *et al.* (2020) indicates that sweet potatoes can decrease LDL level, which can additionally lower heart disease, helps to slow down digestion, regulate blood levels, while insoluble fiber moves through the digestive system performing more like a broom and increase stool bulk thereby prevent constipation, hemorrhoids, diverticulosis and colorectal cancer. In addition, psyllium and

pectin, two other forms of water-soluble fiber, are most effective in lowering Low-Density Lipoprotein (LDL) known as the bad type, without affecting High-Density Lipoprotein (HDL) the best type reports nutrients (Stephanie, 2021).

A study carried by Bernhard *et al.* (2004) revealed beneficial effects of ciapo (white sweet potatoes) on plasma glucose and cholesterol levels in type 2 diabetes patients. Thirty participants who got 4 g of Caiapo on a daily basis for twelve weeks saw a decrease in their HbA (1c) from 7.21 to 6.68 mg/ dl, fast blood glucose reduced from 143.7 to 128.5 mg/dl, and two-hour blood sugar showed variation from 193.3 to 162.8 mg/dl. Thirty-one participants who got a placebo instead of ciapo saw no such results. Sweet potatoes are high in antioxidants that prevent free radical damage in body. One cup of baked sweet potato contains 52% of daily need for vitamin C, which is very important for wound healing and tissue repair (Ooi and Loke, 2013).

Phytochemical screening discovered excessive per cent of carbohydrate, decreasing sugar and phenolics in White Flesh Sweet Potato (WFSP), while OFSP confirmed improved stages of general protein, flavonoids, anthocyanins, and carotenoids (Rajendran *et al.,* 2014). The degradation rate of starch and cellulose become discovered to be much less in OFSP for the duration of storage, indicating tight regulation of gene(s) responsible for starch-degradation (Ayeleso *et al.,* 2018). Diet rich in fruits and vegetables like sweet potatoes lower the risk of cognitive decline by 13% (Terahara *et al.,* 2004). In addition to causing cancer, free radicals can damage cells in the neurological system, including brain and spinal cord. Axerophthol (vitamin A) in sweet potato protects epithelial tissue and mucous secretion integrity within the body. Epithelium lines the outer surface of the internal organs, which protects cells from infection (Shyur *et al.,* 2021).

The prevalence of Bitot spot is 0.7 to 2.2 % and avitaminosis is 1.2 to 4.0 % within the eastern region (Assam, Bihar, Orissa, West Bengal & Tripura). Beta carotene - a necessary anti-oxidant for eye health, is extensive in OFSP (Remya and Mohanraj, 2018). Sweet potatoes conjointly contain moderate levels of zinc, another vital mineral for eye health. The age-related disease study evaluated the effectuality of zinc in preventing devolution (Park *et al.,* 2018). A study have also found consumption of foods rich in mineral considerably reduce the severity of age-related macular degeneration

and warded off vision defect ensuing from the condition (Neela *et al.,* 2019). High potassium content in sweet potatoes helps body to cancel out the negative effects of salt and aids kidneys to function more efficiently so one can flush excess sodium from the body, lowering blood pressure naturally (Steed *et al.,* 2008). Too much pressure on the veins puts stress on the kidneys, increasing the risk of stroke, hypertension and congestive heart failure and the potassium content in sweet potato helps to regulate the blood pressure levels (Shi *et al.,* 2021).

Anthocyanins are phenolic compounds liable for the extreme color of the many fruits and vegetables such as red grapes, berries, red cabbages and purple sweet potatoes (Mazza *et.al.,* 1993). In addition to use as food colourants, anthocyanins have incontestable nutraceutical functions and high in sweet potato. Anthocyanins might stop multiple chronic diseases such as cardiovascular disease (Blumberg, 2007), polygenic disease (Konishi, 2007), cancer (Wang and Stoner, 2008), and age-related neurodegenerative decline (Senevirathna *et al.,* 2021). Vitamin A and carotenes reduce macular degeneration, night blindness, and strengthens vision before the age-related degeneration from free radicals occur (Sanjeev *et al.,* 2009).

The sweet potato can be considered as a wonderful novel supply of natural health-promoting compounds, corresponding to carotenoid and anthocyanins, for the functional food market. The effects of the distinctive anthocyanins within the sweet potato on colorectal cancer hindrance and the underlying mechanisms are mostly unknown. Anthocyanin enriched sweet potato P40 could defend against large intestine cancer by inducement of cell cycle arrest, anti-proliferative and apoptotic mechanisms (Chen *et al.,* 2019). In addition to a high content of total phenolics and antioxidant capacity, P40 possess a high content of anthocyanins. Type 2 diabetes and obesity is reversed by anthocyanins, by altering the way of carbohydrate metabolism in large intestine (Kilua *et al.,* 2019). Sweet potatoes provide an upscale supply of antioxidants with anti-cancer properties particularly within their skin. Sporamin has been studied for anti-cancer ability and found to be effective in many disease types (Kuyu *et al.,* 2019). Analysis has been proven the use of sporamin to inhibit tongue, gallbladder, and colorectal cancers and capability in deceleration of neoplastic cell growth, reducing cell migration and invasion in pathological process cancers (Musyoka *et al.,* 2018).

Sweet potato peels, notably those of the purple varieties, is also particularly powerful and is involved in cancer prevention. A study revealed in Nutrition associate degreed Cancer in 2016 checked out the antioxidant and anti-cancer effects of an extract from sweet potato peels and reported a promising anti-cancer activity for cancers of the breast, colon, ovary, lung, and head/neck (Chen *et al.,* 2008). Researchers evaluated the effect of foods rich in this nutrition for combating lung cancer. Study participants who often consumed sweet potato considerably reduced their risk of developing this disease (Ku *et al.,* 2008). Approximately around 80% of the protein in sweet potatoes may be a sort of antiviral drug with potential anti-cancer effects (Meents *et al.,* 2019). Sporomins are tested against colorectal cancer cells, one of the most common and deadly cancers, and have found to reduce the expansion of carcinoma cells as well its migration and invasion (Yeh *et al.,* 2016).

C. Vitamin C rich fruits and human health

Vitamin C is one of the safest and simplest nutrients and the tolerable higher intake level is 2000 mg a day for adults (Padayatty and Levine, 2016). Recommended dietary intake of vitamin C is 75 mg for adults. Vitamin C protect against system deficiencies, cardiovascular disease, prenatal health problems, eye disease, and even skin wrinkling (Yin *et al.,* 2022). It aids in the regeneration of skin, vessels, cartilage, and connective tissues, and it promotes collagen production in the skin. Lack of vitamin C can lead to serious diseases such as heart disease and cancer. It can also lead to hair and skin problems, as well as gum disease. Vitamin C detoxifies the body, lowers blood pressure, and is a natural remedy for upper respiratory tract diseases such as colds, flu, and colds . It prevents scurvy, lowers the risk of stroke, protects cardiovascular health, aids in cell and tissue regeneration, and eliminates cancer-causing factors. It is effective in the treatment of diabetes, which affects a large portion of the population. It has anti-inflammatory properties and can be used to treat both chronic and acute infections (Padayatty and Levine, 2016). Fruits rich in vitamin C are orange, lemon, grapes, strawberry, kiwi, gooseberry, grapefruit, tangerine, melon, blueberry, blackcurrent, mango, pineapple, rosehip, apple, guava, dates, nendran etc.,

The botanical name of apple is *Malus Domestica*. An apple contains 86% water and 14% carbohydrates, with negligible fat and protein content. A 100-gram serving of raw

apple with skin contains 52 calories and a moderate amount of soluble fiber (Jia *et al.,* 2021).Apple toffee is a traditional confectionery prepared by coating an apple in hot toffee and cooling it. Caramel apples are coated with chilled caramel and candy apples are coated in a hard shell of crystallized sugar syrup. Apples are used in a variety of desserts, including apple pie, apple crumble, apple crisp, and apple cake. Apples are also used to make apple butter and apple jelly, and cooked apples are used to make sauce. They are frequently baked or stewed, and they are also used in some meat dishes (Han *et al.,* 2018). There are lot of varieties in apples such as Pink lady, Empire, Fuji, Gala, Golden delicious, Granny smith, Honey crisp, Mcintosh, Red delicious etc.,. While comparing these varieties red delicious and honey crisp have 12.2-12.4 mg of vitamin C and is highest of all (Askew and Kidson, 2000).

Dried apples can be eaten whole or reconstituted by soaking them in water, alcohol, or another liquid. Apples are milled or pressed to make apple juice, which can be filtered or unfiltered and referred to as apple cider (Hao *et al.,* 2017). Filtered juice is frequently concentrated and frozen before being reconstituted and consumed. Hard cider, ciderkin, and vinegar can all be made from apple juice that has been fermented.

By distillation of apple juice variety of alcoholic beverages, including applejack, Calvados, and apfelwein are produced (Itai, 2015). The ascorbic acid content of apples varied greatly depending on their types. Malic acid and sucrose are positively correlated with altitude, while glucose is negatively correlated. Malic acid was significantly associated with ascorbic acid and sucrose, and glucose (Li *et al.,* 2021).Sugars and acids are the most important phytochemical components of apples, and they have a major impact on the overall organoleptic quality of the fruits (Nour *et al.,* 2010).In moderation, apple juice consumption has a positive effect on markers of cardiovascular health, which may eventually be relevant for cancer and neurodegenerative diseases (Vallee *et al.,* 2022).The apple peel had higher antioxidant activity and mineral composition than the pulp, stating significant differences between the parts of the fruit. As a result, eating apples with their peels may be recommended in order to gain greater nutritional benefits (Manzoor *et al.,* 2012).

The apple peel contained the most melatonin of any edible part of the apple. Melatonin was consumed during the juicing process as a result of its interaction with the

oxidants. The addition of melatonin significantly reduced the browning of the juice. Melatonin scavenges free radicals, as evidenced by apical sodium bile acid transporter analysis, thereby inhibiting the conversion of o- diphenolic compounds into quinones. Most importantly, in apple juice, melatonin demonstrated potent anti-microorganism activity. Melatonin's effects can help to preserve the quality and shelf life of apple juice (Zhang *et al.,* 2018). Carotenoid composition differed by apple variety, with yellow-skinned apple peels having slightly higher total carotenoid content than red-skinned varieties. The peels of red skin apples, on the other hand, had a higher total phenolic content. Anthocyanin profile was predominated by cyanidin-3-O-galactoside. Apples have a greater phytochemical content with diverse compositions, and they can be an excellent source of antioxidants when consumed on a regular basis (Vasile *et al.,* 2021).

Polyphenols found in apples, such as flavonoids, have been shown to have antioxidant, anticancer, antibacterial, anti-inflammation, cardioprotective, and immune modulator properties (Tungmunnithum *et al.,* 2018).Apples contain proanthocyanidins, which have antimicrobial, anticancer, antiproliferative, and antiangiogenic activity, as well as antihypertensive, anti-obesity, neuroprotective, and antiaging properties (Unusan, 2020). Furthermore, dihydrochalcones in apples have been shown to have cardioprotective, anti-cancer, anti-obesity, anti-diabetic, antioxidant, anti-aging, hyperglycemia, anti-microbial, and anti-inflammatory properties (Patocka *et al.,* 2020).

Apples contain five major groups of phenolic compounds. They are hydroxycinnamic acids, flavan-3-ols, flavonols, dihydrochalcones, and anthocyanins. These groups of biologically active phenolic compounds determine the apple's colour shades and sensory properties, which influence the fruit's vegetative maturity and quality indicators (Serra *et al.,* 2012). Apple polyphenols may also have a positive impact on Alzheimer's disease outcomes. Apple juice may help with normal ageing cognitive decline by suppressing the over expression of presenilin-1, which is linked to the production of amyloid b peptide, a marker of Alzheimer's disease (Chan and Shea, 2009). The apple ethanol extracts contained the highest quantity of phenolic compounds and flavonoids, as well as the highest antioxidant activity. The HPLC method confirmed that phloridzin was the most abundant component in the apple

ethanol extracts. Hyperoside, isoquercitrin, avicularin, rutin, and quercitrin were the other quercetin glycosides discovered (Liaudanskas *et al.,* 2014).

The botanical name of dates is *Phoenix dactylifera*. Varieties in dates include Ajwa, Anbara, Safawi, Barhi, Medjool, Saghai, Khudri, Zahidi, Sukkari etc., Medjool dates have a similar nutritional profile to Deglet Noor dates and are frequently larger in size (Ishurd *et al.,* 2004). Dates are high in protein, vitamins, and minerals, in addition to tasting delicious. They also contain a lot of polyphenols (Amira *et al.,* 2011). Dates contain 66 calories per date, or 275 calories per 100 g. Carbohydrates account for the majority of its calories. Dates have 98 % of carbohydrates and 2 % of protein (Haider *et al.,* 2013). Dates are rich in iron and contain 10.4 mg of iron per 100g (Mousavi, Rafiei and Yoosefpour, 2014). Date fruit is a significant product in the world, and plays an important role in the economic and political life of dates growing regions. The date palm (*Phoenix dactylifera L.)* is a monocotyledon plant.

Dates are primarily composed of water, sugar, protein, fat, pectin, ash, crude fiber, and polyphenols (Alqahtani *et al.,* 2021). Washing, grading, thermal treatment, drying, sterilisation, irradiation, moistening, pitting, pasteurization, coating, and packaging are all part of the date processing process. Semi-finished and ready-to-use date products, date-derived products such as date juice, date syrup, date spread, liquid date sugar, "Tarooneh" arrack, and sago, are examples of processed form of dates. Dates contain sugar and phenolic compounds, and they have excellent antibacterial activity against the majority of the bacteria tested. They are high in potassium, selenium, copper, phosphorus, iron, and manganese. Mannoic and lactone, two bioactive compounds, were also found in dates. They are high in sugar, alcoholic sugar, aromatic hydrocarbons, phenols, and esters (Alhamdan *et al.,* 2018).

Dates have proven to have enormous potential for use as a therapeutic agent for treating mineral deficiency and for the development of antibacterial agents (Perveen and Bokahri 2020).Date fruit consumption improves colon health by increasing useful bacterial growth and inhibiting colon cancer cell proliferation. Dates consumption by humans may help to maintain bowel function and even reduce the development of colorectal cancer (Eid *et al.,* 2014).Dates are considered as an effective treatment for reducing risks of infertility due to their antioxidant potential.In males, the date palm has

a powerful effect on reproductive parameters such as hormonal levels and seminal vesicle parameters, as well as sperm motility, count, and viability; whereas in females, it has a powerful effect on reproductive parameters such as oogenesis, oocyte strengthening, hormone regulation, pregnancy strengthening, labour augmentation reduction, and postpartum haemorrhage prevention (Shehzad *et al.,* 2021).

Date fruits are one of the fruits that have been reported to have good potential in the treatment of diabetes due to the presence of polyphenols that have strong antioxidant properties (Peng *et al.,* 2013). Polyphenolic compounds, which can limit enzymes like -amylase and glucosidase, are another possible mechanism of action (Carughi *et al.,* 2016). Date flavonoids can stimulate beta cells by increasing the number of islets and beta cells, convalescing endocrine pancreatic tissues, reducing beta cell apoptosis, activating insulin receptors in response to increased insulin secretion, and improving diabetes-related complications (Mia *et al.,* 2020).

Date products or their polyphenol fractions appear to modulate plasma lipid levels, indices of oxidative stress, and inflammation, all of which are associated with improved cardiovascular health (Dashti *et al.,* 2021). Increased serum homocysteine levels have been linked to an increased risk of CVD. Folic acid is required for the conversion of homocysteine to methionine. Dates are high in folic acid and vitamin C (Kaye *et al.,* 2020). Most date varieties are high in potassium and low in sodium, which are both major nutritional factors in maintaining normal blood pressure (Aburto *et al.,* 2013). While the vitamin C content of dates is low in comparison to most citrus fruits, it can still help to scavenge free radicals through enzymatic and non-enzymatic activities, as well as defend lipoproteins from oxidation**.** Furthermore, vitamin C enhances indicators such as arterial pressure and endothelial function and decreased serum vitamin C concentrations have been linked to an increased risk of CVD. Oxidative stress protection by dates was attributed to increased activity of oxidant defence enzymes such as catalase (CAT), superoxide dismutase (SOD), glutathione peroxidase, glutathione reductase, and glutathione S-transferase, as well as a significant reduction in malondialdehyde (Neweshy *et al.,* 2013)**.**

The botanical name of guava is *Psidium guajava*. This sweet, slightly acidic variety is nutritious and has sweet and slight acidic taste. The Tropic White Guava is

named after its white flesh. The peels of these guavas are bright yellowish green, and the flesh is creamy white. Guava fruit is high in vitamins A and C, folic acid, fiber, and minerals like iron, manganese, potassium, and copper (Kumar *et al.,* 2020). A single guava fruit contains roughly four times the amount of Vitamin C as an orange. So, guava is known as the "poor man's apple of the tropics**" (**http://www.rain-tree.com/guava.htm).The Tropic White Guava is named after its white flesh. The peels of these guavas are bright yellowish green, and the flesh is creamy white.

Guava instant drink powder is to be obtained by using various drying techniques that result in the preparation of dehydrating the concentrated juice of guava (Kadam, *et al.,* 2012). The removal of water from guava juice and conversion to powdered form results in a significant reduction in quantity and is one of the effective methods for extending the shelf life of fruits (Osorio, *et al.,* 2011). Guava is preserved and processed into jam, jelly, guava preserve, nectar, alcoholic bevereges, etc., (Ayub et al., 2005). The thermal resistance of quality deteriorating enzyme of guava was found to be greater than that of commonly reported harmful bacteria such as *Saccharomyces cerevisiae* and *Lactobacillus plantarum* for processed fruit products (Lin *et al.,* 2016). The most thermally sensitive enzyme was aldehyde oxidase. Lycopene was found to be heat stable, whereas alpha amylase showed less heat stability and was negatively affected in the process of enzyme inactivation (Vishwasrao and Ananthanarayan, 2018). Guava pulp extracts contain a wide range of constituents, the main ones are bioflavonoids. Guava could protect against cholestatic liver injury and cell proliferation in cholangiocarcinoma. Guava juice had 42.38 % antioxidant activity against 1,1-diphenyl-2-picrylhydrazine (DPPH) radical and 33.45 % antioxidant activity against hydroxyl radical. Mass spectroscopic analysis of soluble guava extract revealed the presence of antioxidant and antimicrobial compounds such as esculin, quercetin, gallocatechin, 3-sinapoylquinic acid, gallic acid, citric acid, and ellagic acid (Sampath *et al.,* 2021).

Guava extract significantly reduced fasting blood sugar, total cholesterol, total triglycerides, glycated serum protein, creatinine and malonaldehyde while exhibiting good DPPH and 2,2′-azinobis- (3-ethylenebenzothiazoline)-6-sulfonic acid (ABTS) free-radical scavenging abilities (Luo *et al.,* 2019). Although guava has a variety of medicinal qualities, it is the most popular conventional remedy for gastrointestinal infections such

as diarrhoea, dysentry, stomach aches, and indigestion, and it is used for these ailments all over the world (Gutierrez *et al.,* 2008). With its multiple modes of action, guava extract may help to reduce the development of drug resistance to some infectious diseases (Anand *et al.,* 2016). Guava has been shown to be effective against gastrointestinal infections, malaria, respiratory infections, dental infections, skin infections, diabetes, hypertension, cancer, malnutrition, women's problems, pain, fever, liver problems, and kidney problems (Alnaqeeb *et al.,* 2019).

The botanical name of nendran is *Musa Paradisiaca.L.* Bananas have a higher antioxidant capacity than some berries, herbs, and vegetables due to the presence of phytochemicals. Banana puree, concentrate, pulp, wine, beer, chips, wafers, banana powder, and value added products are all processed forms of nendran banana. Banana powder is a powder made from bananas that have been processed (Pommerrenig *et al.,* 2006). It is a component used in the production of milk shakes and baby foods. Banana pulp is high in essential phytonutrients such as phenolic compounds and vitamins (B3, B6, B12, C and E). Banana lectin (BanLec) is a highly stable and protease resistant protein found in the pulp of matured nendran (Chauhan *et al.,* 2016).BanLec can elicit an immune response and has been shown to be a potent mitogen for murine and human T cells and also can stimulate macrophage activity, inhibit HIV1 reverse transcriptase activity, and suppress cancer cell proliferation. BanLec has the potential to be a powerful protein for oral antihapten immunization in humans (Singh *et al.,* 2014). Bananas are high in minerals like potassium and phosphorus. The pulp and peel contain phenolic compounds such as catechin, epicatechin, lignin, tannins, anthocyanins, vitamins (A, B, C, and E), and carotene. Catecholamines such as norepinephrine, tryptophan, indole compounds, pectin, dopamine, and serotonin have been discovered in banana pulp. Banana pulp and peel contain phenols, carotenoids, flavonoids, biogenic amines, phytosterols, and other phytochemicals (Pereira and Maraschin, 2015). Carotenoids, flavonoids, amine compounds, and dietary fiber are also present. The carotenoid reported in bananas was lutein, which exhibited antioxidant properties as well as an inhibitory effect on age-related macular degeneration (Davey *et al.,* 2006). In an aqueous extract of unripe nendran pulp, a

unique flavonoid known as leucocyanidin was discovered, that is now recognised to be effective in the treatment of gastric diseases (Lewis *et al.,* 1999).

Nendran banana (*Musa paradisiaca L.*) flesh and peel contain significant amounts of moisture, fiber, carbohydrates, and low fat content, while minerals K, Mg, Ca, Na, P, and N were significantly concentrated in the peels and pulp extracts in particular (Bezemer *et al.,* 2015). According to the World Health Organization, the anti-nutrients alkaloid, oxalate, saponin, and phytate were detected in safe amounts in nendran banana (WHO, 2017). Because of the predominance of the α-carotene and β -carotene, with organic acids and sugars as the primary polar metabolites, nendran banana contains high amounts of provitamin A carotenoids (Chandra *et al.,* 2020).

Many phenolics were found in banana, including ferulic, sinapic, salicylic, gallic, p-hydroxybenzoic, vanillic, syringic, gentisic, and p-coumaric acids. Nonetheless, ferulic acid had the highest concentration of all phenolics (Russell *et al.,* 2009). The main flavonoids found in bananas are quercetin, myricetin, kaempferol, and cyanidin, and provide health benefits primarily by acting as free radical scavengers (Kevers *et al.,* 2007). Phenolic compounds in banana have a variety of biological effects, including antiviral, antibacterial, antiallergenic, anti-inflammatory, vasodilatory, and antithrombotic functions. These benefits are primarily due to their action as free radical scavengers (Ali *et al.,* 2021). Nendran is primarily composed of starch, as well as proteins, fat, ash, and dietary fiber. Nendrans are also high in calcium, vitamins A, B1, B2, B3, B6, C, and minerals like potassium and phosphorus (Osundahunsi, 2009). Nendran is used in folk medicine to treat diseases such as ulcers, wound healing, and many others due to its anti-ulcerogenic, antimicrobial, anti-urolithiatic, and analgesic properties. For its anti-ulcerogenic properties, the flavonoid leucocyanidin has already been recognized as the main ingredient in nendran (Lweala *et al.,* 2011).

D. Chemical changes and nutritional changes in fruits on processing

The macro- and micro-structural changes, moisture absorption, and acid utilization in sweet potatoes during simulated gastric digestive processes as influenced by cooking method were investigated, and the results show that during cooking, sweet potato develops structural modifications, which influence its digestion behavior. Sweet

potatoes encounter various structural changes during cooking, which influence the cellular metabolism. Cooking method influenced changes in macro and micro structures, moisture and acid uptake in gastric digestion. Possibility of using sweet potato endogenous amylases to make complementary porridges with drinkable densities and relevant macronutrient densities for kids with differing energy needs (Nabubuya *et al.,* 2017). Overall, the characteristics of sweet potato parenchyma cells (SPPC) could be the outcome from perfectly preserved parenchyma cell walls surrounding clusters of SPPC granules, and SPPC could be considered an alternative to sweet potato starch flour (SPFL) and sweet potato starch (SPST) for expanding industrial applications of sweet potato (Lee and Kim, 2019). Only 3.5 % of the RDA was provided by 115 g of homemade OFSP-puree. The combination of pumpkin to OFSP had no effect on the percentage of recommended daily allowance. Intriguingly, adding an emulsifier (egg yolk powder) before cooking can increase the percentage of provision by a factor of 2.7. These findings indicate that striking a balance between formulation and processing is critical for maximizing carotenoid bioaccessibility of carotenoids in OFSP-based baby food (Mayer *et al.,* 2018).

The polarizability of sweet potato slices reduced as moisture content decreased. Henderson and Pabi's model could predict the difference in dielectric properties of sweet potato slices and could be used to evaluate the modification in water content of sweet potato during thermal processing (Lee *et al.,* 2018). Sweet potato cellular damage is caused by the activities of microbial enzymes, specifically pectinases of organisms isolated from contaminated potato tissues, and suggests the benefits of using iprodione as an adhesive for potato tubers prior to cooking (Oladoye *et al.,* 2016). Total control of process conditions and raw material configuration may allow for longer shelf - life and potentially health improvement credentials for the product. These study results are unique to sweet potato crisps, but they are also useful to the food industry as a whole (Agarwal *et al.,* 2021).

The use of anti-browning chemical agents confirmed the synergistic preservative effect on the colour of minimally processed apples when combined with the dipping treatment, while structural decay of fruit tissue was evident (Emiliano *et al.,* 2006). Cooking apples reduces their vitamin C content because this nutrient is particularly

sensitive to heat. Most of the fiber and phytochemicals can be retained if cooked with the skins on. Because the fiber is mostly found in the skins, peeling apples will remove the majority of the fiber. According to the University of California, San Francisco, the amount is about 17 to 20% of the daily recommended fiber intake and cooked apples contain more of vitamin C (Diane, 2007). Microwaved apples contain 0.3 mg of vitamin C per 100 g, whereas boiled apples have 0.2 mg. Cooked apples have lower levels of thiamin, riboflavin, niacin, vitamin B-6, folate, vitamin A, and vitamin E. Polyphenols are abundant in both raw and cooked apples, though the amount decreases when the apples are cooked.

Polyphenols act as antioxidants in the body, aiding in the prevention of conditions such as cardiovascular disease (Susan, 2018). The removal of the peel eliminates much of the fiber as well as the majority of the flavonoids. Dehydrating or drying the apples removes the vitamin C found primarily in the flesh. Clear apple juice is filtered and pasteurized, which removes the majority of the flavonoids and fibers (Koutsos *et al.,* 2015). Apple juiciness was measured by assessing electrolyte release in cellular fluids throughout compression tests. The change in mass was very small at each temperature when compared to the sample volume. The electrical indicator LTO showed apple cell membrane damage at 60 and 80 °C, which decreased mechanical properties but increased juiciness. The mechanical properties and juiciness of the heated apples were influenced by cell membrane damage (Takashi *et al.,* 2019).

Fruit syrup prepared from guava performed best in terms of pulp and TSS in the treatment 20% pulp and 15% brix, TSS, acidity, reducing sugar, and viscosity all increased during storage, while all sensory characteristics decreased (Ashok and Pradip, 2019).When the guava pulp was treated with 500 and 750 ppm of sulphur-dioxide in the form of potassium meta-bi sulphite alone and in combination with heating at 85°C for 5 minutes, there was an increase in acidity, total sugars non-enzymatic browning, and a decrease in ascorbic acid and sulphur-dioxide (Harsimrat and Dawan, 2004).In terms of less browning, retention of more ascorbic acid, and good keeping quality, potassium sorbate and potassium metabisulphite (KMS) at 0.1 percent alone and in combination with heating at 85°C for 5 minutes in guava pulp produced better results than potassium sorbate (Mahajan, 2011). While analysing qualitative

characteristics flavour, taste, colour, texture, and overall acceptability and colour a* and b* value, after the storage of 90 days they wereretained better in low temperature of about -20°C, while adding potassium meta bi-sulphite of 0.1%, sodium benzoate with potassium meta bi-sulphite 0.05 % each, and potassium sorbate of 0.1%. The degradation of ascorbic acid and the production of furfural may cause flavour and taste loss (Pilania *et al.,* 2014). During storage, the vitamin C and acidity of the guava extract decreased, while the pH and TSS increased. Fruit pulp discoloration and browning are caused by a variety of reactions, including maillard condensation of hexoses and amino components, phenolpolymerization, and pigment destruction.

Date processing includes not only processed products but also basic treatments for hygienic and quality control purposes, as well as stabilization for a longer shelf life. Fumigation, cleaning or washing, drying, sorting and grading, and packaging are all basic and necessary steps. Moisture, sugars, enzymes, fibers, volatiles, minerals, phenolics, and antioxidant activity are all intrinsic parameters that affect the quality of fruit during processing (Salah *et al.,* 2015). A premixed date bar (including almonds and corn starch) supplemented with soy protein isolate, single cell protein and dry skimmed milk produced a nutritionally balanced mixture that scored well with moderate variations in sensory testing when compared to the control, even after prolonged storage up to 6 months at 7° C and 25° C (Barreveld, 2004).

Banana pulp had a positive relationship with the water solubility index, total minerals, and iron content, but a negative relationship with the water absorption index (WAI), protein, and overall acceptability. According to the response surface analysis, yield increased with incubation time, cellulase and pectinase concentration, and temperature, which initially increased and then decreased. The viscosity was affected in the opposite way by the processing parameters. All processing parameters had an effect on sugar content reduction (Handique, Bora and Sit, 2019).By combining peeled bananas with spear grass, a mechanical juice extractor was developed. This method reduced the time required for juice extraction, but it also had a lower yield efficiency of 47% when compared to the traditional method, which had a yield efficiency of 69 percent (Kasozi and Kasisira, 2005).

METHODOLOGY

III. METHODOLOGY

The methodology carried out for the study entitled **"Development of Fruit bar Rich in Beta carotene and Vitamin C"** is given as follows:

A. Selection and identification of fruits
B. Preparation of the juice/pulp from the selected fruits
C. Development and standardisation of fruit bars
D. Sensory evaluation of the fruit bars
E. Analysis of physiochemical properties of the fruit bars
F. Nutrient analysis of the fruit bars
G. Statistical analysis, interpretation of the results and ethical clearance

A. Selection and identification of fruits

Fruits are selected on the basis of their vitamin C content. The fruits selected for the current study are apple (*Malus Domestica)*, dates (*Phoenix dactylifera)*, guava (*Psidium guajava)*, and nendran banana (***Musa Paradisiaca.L)***.

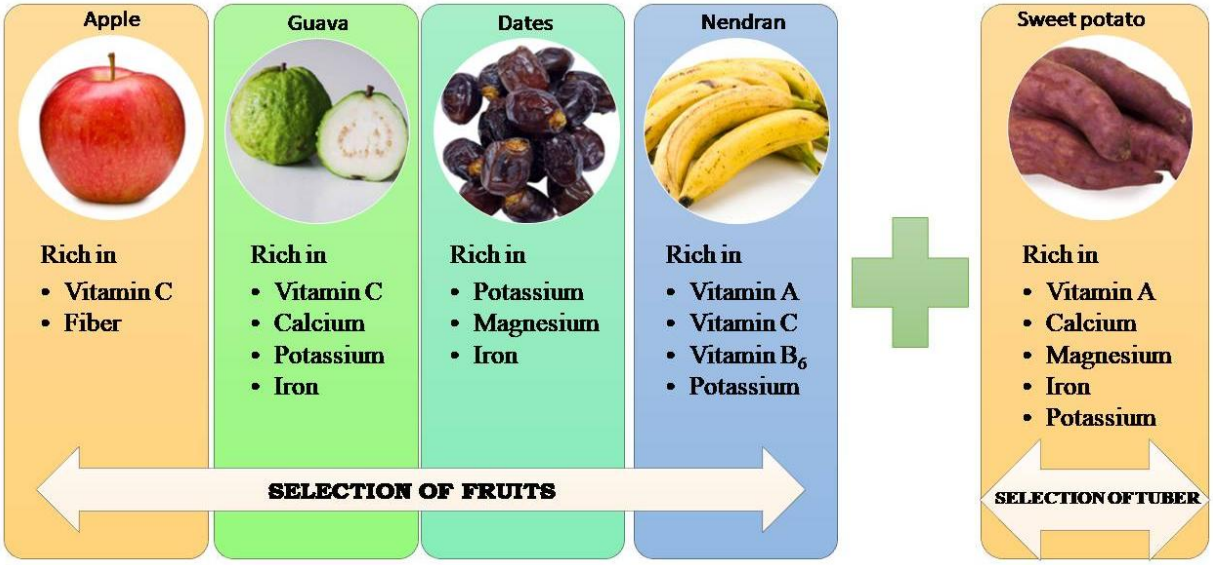


Figure 1
Nutrients present in the sweet potato and selected fruits

Figure 1 represents the nutrients present in the sweet potato and other fruits. Apple is a nutrient variety dense fruit that has a generous amount of vitamin C and fiber; guava is rich in vitamin C, calcium, potassium, and iron; dates are the best source of potassium, magnesium, and iron; nendran banana has a generous amount of vitamin A, C, B_6, potassium and low levels of iron and magnesium; sweet potatoes are rich in beta

carotene, vitamin B and C, iron, calcium, zinc, magnesium, phosphorous and potassium. All the above-mentioned fruits are combined with sweet potatoes and made into fruit bar. Sweet potatoes and other selected fruits were purchased from the local super market for the standardisation of the fruit bar. The red crunchy variety of apple, white coloured guava, qyno dates and nendran variety banana was identified and purchased. White fleshed sweet potato was identified and purchased along. The selected fruits are available throughout the season and hence procurement was easy.

B. Preparation of the juice/pulp from the selected fruits

The fruits and sweet potato purchased was thoroughly cleaned before processing. Fruit juice is obtained by compressing or grinding the fruit in a blender or mixer. The seeds are removed if it is hard to grind. Fruit bars have glossy texture and extended shelf life when prepared from juice with pulp.

Extraction of apple juice

Bright red coloured fully ripened crunchy apples with no bruises and intact were selected and washed thoroughly by soaking in cold water for half an hour. The core and seeds are removed carefully without edible part using knife. 150g of apple was weighed in a weighing scale. It was blended in a mixer to a soft paste with 30ml of water, and the juice was filtered through muslin cloth to remove the pulp. The quantity of the juice obtained was measured using a measuring cup and the value was recorded.

Extraction of guava pulp

Half-ripened white guava was chosen and properly washed by soaking in cold water for half an hour to remove dirt and other impurities. Fruit was cut into smaller pieces and weighed at 150g. The pulp was grinded in a mixie to a smooth paste by adding 50ml of water. The pulp was obtained after passing the pulp through muslin cloth which removes the seed and hard parts. The quantity of the juice obtained was measured using a measuring cup and the value was recorded.

Extraction of dates pulp

60g of dates was taken and washed with water and soaked in 20ml of boiled cooled water for 2 to 3 hours. The seeds are removed and the fruit was blended in a mixer jar with the water in which the dates was soaked. The pulp was filtered by filtering

the mix through muslin cloth. The quantity of the pulp obtained was measured using a measuring cup and the value was recorded.

Extraction of nendran banana pulp

Fully ripened nendran banana with bright yellow skin was selected and the peel was removed. 150g of fruit was taken and blended with addition of 15ml of water. The obtained pulp was used for preparation of fruit bars without straining as it had no lumps.

Extraction of sweet potato juice

White fleshed sweet potato without bruises and blemishes was selected and washed to remove the mud and dirt. Tips are removed and the tuber was weighed for 100g. It was cut into small pieces and ground in a mixie without any lumps with addition of 50ml of water. The pulp was filtered through muslin cloth, and the juice was obtained to remove any lumps.

C. Development and standardisation of fruit bars

Fruit bars were developed in step by step process by the following methods for standardisation:

Method 1:

100g of sweet potato was boiled in 500ml water to make it tender and soft. After boiling the peel was removed and cut into small pieces. The small pieces are blended in the mixer to make it into a smooth paste. 100g of peeled apple was boiled in 50ml of water and then allowed to cool. Apple was grinded into a smooth paste by adding the water in which it was cooked. 10g of white sugar was weighed separately. The pan was heated and 5ml of water was added along with 10g of sugar. When it reached the soft ball stage of sugar, blended paste of sweet potato and apple was added together. The mix was stirred continuously until it reached a thick paste consistency. It was then poured in the coconut oil greased plate to 2 mm thickness and allowed to sun dry until it was completely dried. The sweet potato – apple fruit bar (SPA) was then cut into desired size. The time taken for drying was noted and recorded. Same procedure was repeated for dates, guava and nendran banana. In this method fruit bar didn’t retain glossy texture.

Method 2

Sweet potato was washed thoroughly to remove the mud and dirt. It was weighed for 100g and then chopped into small pieces. The pieces were blended in a mixer with the addition of 50ml of water. The mix was filtered through the muslin cloth to remove the solid parts and lumps and to obtain clear juice. In the heated pan 8g of jaggery was weighed and added along with 5 ml of water. At the soft ball stage extract of sweet potato was added and allowed to boil for 3 minutes. Then the prepared extracted apple juice was added and allowed to boil until the raw flavour disappeared. The mix was stirred continuously to attain the desired consistency. It was then poured in the coconut oil greased plate to a 2 mm of thickness and allowed to sun dry completely. The sweet potato – apple fruit bar (SPA) was cut into desired shapes and size. The time taken for drying was recorded and noted. Same procedure was repeated for dates, guava and nendran banana.

Method 3

Sweet potato was washed thoroughly to remove the mud and dirt. It was weighed for 100g and chopped into small pieces. The pieces were blended in a mixer with the addition of 50ml of water and the mix was filtered through the muslin cloth to remove the solid parts and lumps and to obtain the clear juice. In a hot pan sweet potato juice was added and allowed to boil for 3 minutes, the point at which the raw flavour disappeared. 6g of jaggery was added to the mixture and extracted apple juice was added in the pan and heated for 2 minutes. The mix was stirred continuously until it reached the desired consistency. It was then poured in the greased plate to 2 mm thickness and allowed to sun dry until it was completely dried. The sweet potato – apple fruit bar (SPA) has then cut into desired shape and size. The time taken for drying was noted and recorded. Same procedure was repeated for all the fruits. As this method was acceptable, method 3 was further proceeded to carry out variations. The stages involved in the preparation and standardisation of sweet potato- apple fruit bar is presented in plates 1 to 4. Plate1 shows the preparation of SPA. SPA codes for sweet potato – apple fruit bar, SPD codes for sweet potato – dates fruit bar, SPG codes for sweet potato – guava fruit bar, SPB codes for sweet potato – nendran banana fruit bar respectively.

Washing

Peeling and weighing

Adding fruit pieces to the mixer

Grinding apple and
sweet potato separately

Constant stirring

Sweet potato-apple fruit bar (SPA)

Plate 1
Preparation of Sweet potato- Apple fruit bar (SPA) using method

Sweet potato ↓ ↓ **Dates**

Sweet potato extract ↓ ↓ **Dates pulp**

Combining sweet potato extract and dates pulp

↓

Sweet potato – dates fruit bar (SPD)

Plate 2
Preparation of Sweet potato – Dates fruit bar (SPD) using method 3

Sweet potato **Guava**

Sweet potato extract **Guava pulp**

Combining sweet potato extract and dates pulp

Sweet potato - guava fruit bar (SPG)

Plate 3

Preparation of Sweet potato- Guava fruit bar (SPG) using method

Sweet potato ↓ ↓ **Banana**

Sweet potato extract ↓ ↓ **Guava pulp**

Combining sweet potato extract and banana pulp

↓

Sweet potato – nendran banana fruit bar (SPB)

Plate 4

Preparation of Sweet potato - Nendran banana fruit bar (SPB) using method 3

After carrying out trials for development of fruit bar, the method that gave good results in terms of texture and consistency, taste and appearance, the best method of preparation was identified. It was observed that method 3 was the best, variations was tried out by varying the ratio of the fruit and by inclusion of agar agar in defined quantities. Table 1 represents the variations used in the fruit bar preparation.

TABLE 1

VARIATIONS USED IN PREPARATION OF FRUIT BAR

Variation	Sweet potato (g)	Fruit (g)	Jaggery (g)	Agar agar (g)
1	100	150	6	1
2	100	150	6	0
3	100	100	6	1

Variation 1

Method 3 was repeated with 100g of sweet potato and 150g of fruit juice. In another vessel 1g of agar agar was added with 5ml of water. It was double boiled until the agar agar completely dissolved and reached liquid consistency without lumps. The liquid agar agar was added to the boiling mixture and stirred for about 1 minute. The mixture was poured in a greased plate to 2 mm thickness and allowed to sun dry until it was completely dried. The bar was cut into desired size and shape. Time taken for drying was noted and measured. Same procedure was repeated for dates, guava and nendran banana.

Variation 2

Method 3 was repeated except for varying the quantity of sweet potato and fruit. In variation 2, 100g of sweet potato and 150g of fruit juice/ pulp was used for the preparation of the fruit bar.

Variation 3

Method 3 was repeated for variation 3. In another vessel 1g of agar agar was added with 5ml of water. It was double boiled until the agar agar reached liquid consistency without lumps. The liquid agar agar was added to the boiling mixture and stirred for about 1 minute. The mixture was poured in a greased plate to 2 mm of thickness and

allowed to sun dry until it was completely dried. The bar was cut into cubes. Time taken for drying was noted and measured. Same procedure was repeated for dates, guava and nendran banana.

D. Sensory evaluation of the fruit bars

Sensory evaluation is a scientific method for eliciting, measuring, analysing, and interpreting responses to products as perceived by the senses of sight, smell, touch, taste, and sound. The sensory qualities and the overall acceptability of the formulated fruit bars made using apple, guava, dates, and nendran banana with sweet potato were evaluated.Sensory evaluations should be conducted in a quiet, well-lit space free of odours. The nine-point hedonic scale is the most prevalent, scale used for evaluating a food product with 1 indicating extreme dislike and 9 indicating extreme like. The hedonic scale assumes that participants preferences are on a spectrum and their responses can be classified into two categories as like and dislike. Panel members are a group of testers who have been selected to take part in a sensory test and have been asked to rate the food quality of the items under consideration (Adelakun *et al.,* 2005). Thirty semi-trained panel members who are pursuing their post-graduation from the Departments of Food Science and Nutrition and Food Service Management and Dietetics were involved since they have knowledge about the sensory evaluation and its criteria to be assessed.

The fruit bars are prepared in the Foods Lab, Avinashilingam Institute for Home Science and Higher Education for Women, which is part of the Department of Food Science and Nutrition. Sensory evaluation was conducted in the Food Sensory Laboratory, Avinshilingam Institute of Home Science and Higher education for women, at a time between 10.30 am to 12 pm in the forenoon. The panel members are served with four fruit bars separately with mango fruit bar as standard and three above mentioned variations to taste at various times. All of the products had consistent and uniform portion sizes. During the sensory review, each panel member was given their own time to analyse the product. The panelists were given the fruit bars along with towel and a glass of water. The final products are carefully organized and labelled as Standard, Variation I, Variation II, and Variation III and coded respectively before being delivered to the panel members. A pen and a score card of nine point hedonic scale

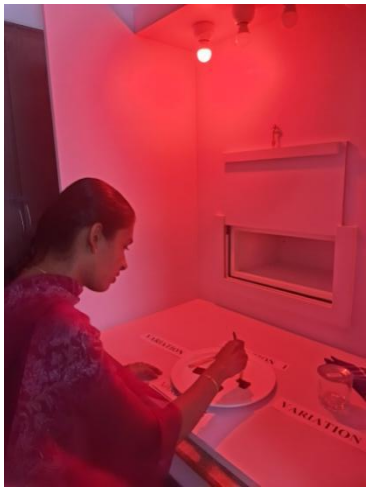
were distributed to the panel members. The evaluation card was prepared legibly, and the material was organised in a logical order for the examination that is required for each test. The panel member's scores were used to determine the acceptability and organoleptic scoring of the fruit bar. The results of the panel member's sensory evaluation of the products were recorded, and the mean scores for each product were determined. Each product's overall acceptability and mean scores were evaluated, and the product with the highest total and mean scores were deemed to be most acceptable. Plate 5 represents the sensory evaluation of fruit bar. The score card used for evaluation of the fruit bar is presented in Appendix II.

Appearance

In the food industry, vision is the most widely used parameter for assessing appearance characteristics. There is a connection between the colour and the decision to eat or not to eat the product. Because of the complexity of the appearance properties of foods, their heterogeneous nature, and the short-season or batch nature of manufacture, sophisticated colour measurement and matching techniques are frequently unnecessary, unworkable, and uneconomical (Guine *et al.,* 2020). Furthermore, the visual assessment is widely regarded as being simple to set up. Fruit bars should be glossy, transparent, and have an appealing colour. The appearance of a food surface is a property that human vision can detect (James Giese, 2013). It can be divided into four types: diffuse reflection (shiny), specular reflection (glossy, mirror-like), diffuse transmission (cloudy, opaque), and specular transmission (cloudy, opaque) (translucent).Plate 5 represent the sensory evaluation of fruit bars.

Texture

The texture of the fruit bar was affected by water absorption, protein, pectin content of fruits, moisture, and sugar. Fruit bars are transparent and neither gummy nor sticky, usually possess characteristics like jelly, and have a firm texture, not hard, rubbery, loose, or flowing like a liquid. Texture is assessed by its ability to stretch, break, flow, bend, etc., In sensory evaluation, texture is evaluated by chewing the fruit bar (Adelakun *et al.,* 2005)



Sensory evaluation by panel member

Analyzing the texture of sample

Tasting of sample

Analyzing flavour of the sample

Evaluation of the sample using score card

Plate 5

Sensory evaluation of the fruit bars with variation I, II and III

Taste

Fruit bars are generally sweet with a mild sour taste due to their acidic pH. It may be affected by the ratio of ingredients, cooking time, and sugar content of the product (Nadeem *et al.,* 2012).

Colour

The colour of fruit usually dominates the colour of fruit bars. It differs from one fruit to another. Some of the fruit bars may be dominated by the type of sugar used in their preparation (Huang *et al.,* 2018).

Flavour

The odour evaluation, which involves smelling the food before it enters the mouth, is performed. When the food is in the mouth, the flavour in the mouth is evaluated. Also included is an after-taste evaluation, which describes the sensations after swallowing a sample fruit bar. A variety of substances can alter flavour perception, allowing them to taste differently (Chaaban *et al.,* 2021).

E. Analysis of physicochemical properties of the fruit bars

Physicochemical properties of food samples are used to evaluate the acceptability of food samples and help in determining the quality deterioration (AOAC, 2000). The physicochemical properties like spread ratio, total soluble solids, colour, texture, acidity, pH and reducing sugar content are examined accordingly with the respective equipment. All the tests were repeated until concordant values are obtained. The physicochemical properties are presented in Plate 6.

Measurement of Spread Ratio

One of the most important properties in determining the quality of fruit bars is the spread ratio. Higher spread ratios are ideal and indicate higher bar quality. It is defined as the ratio of width to thickness (W/T) (Abioye *et al.,* 2015). Thickness was measured using the vernier caliper. Fruit bar was placed between the two jaws such that they touch the opposite ends of each other and make sure that the fruit bar is held tightly but not too tight. The upper jaw was inserted into the cavity and opened till they touch the sides. The screw was tightened and the reading was noted on both the main scle and the vernier scale and the values were added together. The width of the fruit bar was

checked with the ruler. Now the spread ratio was calculated by the ratio of width to thickness.

Measurement of Total Soluble Solids (TSS)

The refractive index determines the total soluble solid content of a solution. This is measured with a refractometer and is known as the degree of brix. Refractometer is used to calculate the percentage of total soluble solids in a pure sucrose solution based on the relationship between refractive indices at 20°C. This determines the concentration of solids in a sucrose-containing solution. Specifically, it is carried out to calculate the concentration of sugar in the fruit bar mixture. At first the light source was turned on. Initially, water is used to calibrate the instrument. Refractometer scale knob was turned on to get the clear interface between the illuminated and dark regions. Using the telescope scale, total soluble solids was calculated (Abbe's Refractometer, 2020). The liquid consistency of fruit bar was used to evaluate the TSS. The lens of the refractometer was cleaned with tissue and the sample was taken in the sample piller and placed in the lens of refractometer. The glass above the lens was closed gently and the value was noted through the telescope scale with an eye view. The examined values were noted.

Measurement of Colour

A colour reader is a device that measures the colour and whiteness of foods or raw materials in paste, solid, or powder form. It has a large LCD screen that displays measurement results from one of eight colour spaces/colorimetric indexes such as L*a*b*, L*C*h, and Yxy. This instrument is used to control the colour of raw materials during the manufacturing process. It can also quantify the impact of storage on the whiteness of a product during transportation (Konica Milota, 2022). The colour reader was switched on and the main page was displayed. In the main page "card search" was selected by pressing the up and down button. On the dropdown list of colour chart, established color library was chosen. The instrument was placed on sample and the test button was pressed. After hearing the sound "beep" the test results of the sample will display on the screen. It shows the closest colour number that matches the sample.

Analysis of Texture

A Texture Analyzer is the ultimate source of objective quantification of whether the food is crispy, firm, sticky, etc. as a result of a new technique or the addition of a specific ingredient to the formulation. It is a texture measurement system that moves up and down to compress or stretch a sample. Texture Analyzers give operators ultimate control and test flexibility for measuring all types of physical/textural properties of solid and semi-solid systems because they can accommodate a wide range of probes and fixtures (devices to test food structure) that can be attached to the texture analyzer base and/or arm. Testing sample was placed between the arms of the instrument. The travelling arm is equipped with a load cell, which records the force response of the sample to deformation. Data on force, distance, and time is collected and typically displayed as a curve on a graph, which when analysed, indicates the texture of the sample (Stable micro systems, 2022).

Measurement of Acidity

10ml of water was added to the fruit bar and further distilled with 25ml of water. The acidity of fruit bar was determined by titration of the distilled fruit juice with 0.1M sodium hydroxide (NaOH), using phenolphthalein as an indicator. The weight of acid was determined by multiplying 0.1M NaOH, the volume of NaOH in a litre and the molecular weight of the acid taken. Total acidity is calculated by multiplying the weight ratio of acid to sample by 100 (AOAC, 2000).

Weight of Acid = 0.1M NaOH X NaOH volume (in litres) X 192.43

% of Acidity = (Weight of acid/ Weight of sample) X 100

Measurement of TSS using refractometer

Measurement of colour using colour reader

Plate 6

Analysis of physiochemical properties

Measurement of pH

A pH meter is an instrument used to detect the pH of fruit bars. Acidic foods contain increasing concentrations of positively charged hydrogen ions. These positive charges are detected by a pH-sensing electrode, which sends a positive voltage (mV) signal to the pH meter. The signal is then compared to a constant reference voltage from the reference electrode by the sensor. 0 mV denotes a neutral solution (pH 7.0), while positive mV values correspond to decreasing pH values (more acidic), and negative mV values denote alkaline solutions, which are less common in foods. The

electrode was immersed in the sample. The button was pressed which in on the top of electrode until the beep sound is out. The displayed readings were noted after they became staple.

Reducing sugar content

Reducing sugar content is determined using the Benedict test. 2 ml of Benedict's reagent was taken in a test tube and 1 ml of fruit juice was added. For 3 to 5 minutes, the test tube was heated in the boiling water bath, or it could be directly heated through the flame. The change of colour and precipitate formation were examined to determine the reducing sugar content.

F. Nutrient analysis of the fruit bars

The nutrients present in the fruit bars was analysed in the Nutrition Laboratory of the Department of Food Science and Nutrition, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, following the standard procedures. They include moisture, ash, fiber, energy, vitamin C, vitamin A, beta carotene, sodium, magnesium, potassium, phosphorous, calcium, and iron. All the tests were done in triplicates to get concordant values. The nutrients analysed in the fruit bar is depicted in the plate 7.

Moisture

Moisture was analysed through moisture analyser. The instrument was turned on and the sample was placed inside the disc and then closed. Weight of the sample was noted. Within 5 minutes the machine displays the moisture content of the sample.

Ash

The ash content of food products is an index of product quality and nutritional value. When a high ash figure indicates the presence of an inorganic adulterant, the acid insoluble ash should be determined. The sample was weighed in the crucible and the crucible is heated in flame. By continuous heating, the substance gets charred which can be used for the determination of minerals present (AOAC, 2000).

Fiber

After grinding and defatting, boiling with a sulphuric acid solution, separation and washing of the insoluble residue, and drying of the insoluble residue, the crude fibre is a mixture of cellulose, lignin, and pentosans, as well as sand, silica, and other mineral

matter locked in the tissues and a little nitrogenous matter. This residue is boiled with sodium hydroxide solution, separated, washed, and dried before the insoluble residue is weighed. It is also noted that mass is lost during incineration. Crude fiber, 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 was found out (AOAC, 2000).

Energy

In the food industry, the Atwater system is used to calculate the total calorific value of food using the 4-9-4 method. In this system, energy conversion factors are applied to the macronutrients carbohydrate, fat, protein, and fiber.

Vitamin C

Redox titration was used to determine the amount of vitamin C in a sample using the reaction between ascorbic acid and 2, 6-dichloroindophenol (DCIP). DCIP is used as a titrant because it oxidises vitamin C and not other substances that may be present, and act as a self-indicator during the titration. To be a self-indicator, a substance must be one colour in the presence of excess ascorbic acid and another colour when the analyte has all reacted. DCIP is red in acidic solutions, but if ascorbic acid is present, it is reduced to a colourless substance. As more DCIP is added, the solution will remain colourless until all of the vitamin C has reacted. As soon as the next drop of DCIP solution is added, the solution will turn light red due to the excess DCIP, and the titration will have ended.

Vitamin A

The sample is saponified with a solution of ethanolic potassium hydroxide, and the vitamin A is juiceed with light petroleum. Evaporation is used to remove the light petroleum, and the residue is dissolved in 2-propanol. The concentration of vitamin A in the 2-propanol juice is determined using reverse-phase liquid chromatography under conditions that produce a single peak for all retinol isomers (AOAC, 2000).

Beta carotene

A beta-carotene stock solution was made by dissolving 10 mg in 100 mL of n-hexane. The stock solution had a concentration of 100 ppm. The stock solution was diluted to various known concentrations, such as 20, 40, and 60 ppm, and dilutions

were obtained in 5 ml of each n-hexane solution. Each working standard solution was injected into the HPLC system when the injector was in load mode. Each sample of beta-carotene juice in acetone was used as a standard for the HPLC assay; each testing sample (20 l) was taken with a microliter syringe. The peak was automatically identified and quantified by comparing the sample's retention time to the standard retention time (AOAC, 2000).

Phosphorous

When the ash solution is treated with ammonium molybdate, phosphomolybdic acid is formed. Phosphomolybdic acid is reduced by the addition of 1,2,4 Amino Naphthol Sulphonic Acid reagent to produce a blue colour, which is apparently a mixture of oxides of molybdenum. The intensity of the colour developed is a measure of the amount of phosphorus present (AOAC, 2000).

Calcium

Calcium is determined by precipitating it as calcium oxalate and titrating the oxalate solution in dilute sulphuric acid against standard potassium permanganate (AOAC, 2000).

Iron

The food sample is oxidised by ignition or oxidation. Ferric iron reacts with ammonium thiocyanate or with potassium thiocyanate to give ferric thiocyanate, which is red in colour. The concentration of the solution is measured using the colorimeter at 540nm, which indicates the concentration of iron present in the sample (AOAC, 2000).

Sodium

The LAQUAtwin B-722 sodium ion metre is used to determine the sodium content of foods. Prior to calibration, the device is set to two calibration points. If the results exceeded the metre’s calibration or measurement range, the sample was diluted with distilled or deionized water (Ehling *et al.,* 2010).

Magnesium

Food magnesium content can be determined by using a flame atomic absorption spectrophotometer. The magnesium absorption is measured after the concentrate is introduced into the flame. The product was weighed for 1g before being placed in a

digestion vessel. The samples are contained in microwave digestion vessels. The vessels were left open for at least 30 minutes to allow gases to escape. After that, the vessels were digested in a microwave digestion system. Spike samples were prepared in the same way, yielding the expected spike concentration of 2 ppm. This method was used to make the sample blanks and spikes. Unless otherwise stated, all samples were prepared in duplicate. Following digestion, the samples were diluted further to ensure that the expected concentration was within the calibration range (Anastasia, 2021).

Potassium

Potassium is determined by atomic absorption spectroscopy by direct aspiration of the filtered or digested and filtered sample into an air- acetylene sample. Effluent samples must undergo a preliminary nitric acid digestion followed by hydrochloric acid stabilization. Plate 7 represents the nutrient analysis of the fruit bar.

Estimation of Moisture

Iron estimation

Vitamin C estimation

Calcium estimation

Plate 7
Analysis of Nutrients

G. Statistical analysis and interpretation of the data

The data was consolidated, tabulated and analyzed statistically to evaluate the sensory characteristics of the developed fruit bars. The research design of the present study is given in Figure 2.

Ethical Clearance

The study was presented in the Institutional Human Ethics Committee, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore and the approval was obtained. The human ethical clearance approval number is AUW/ IHEC/ FSN -20-21/XPD-22 and is appended in Appendix I.

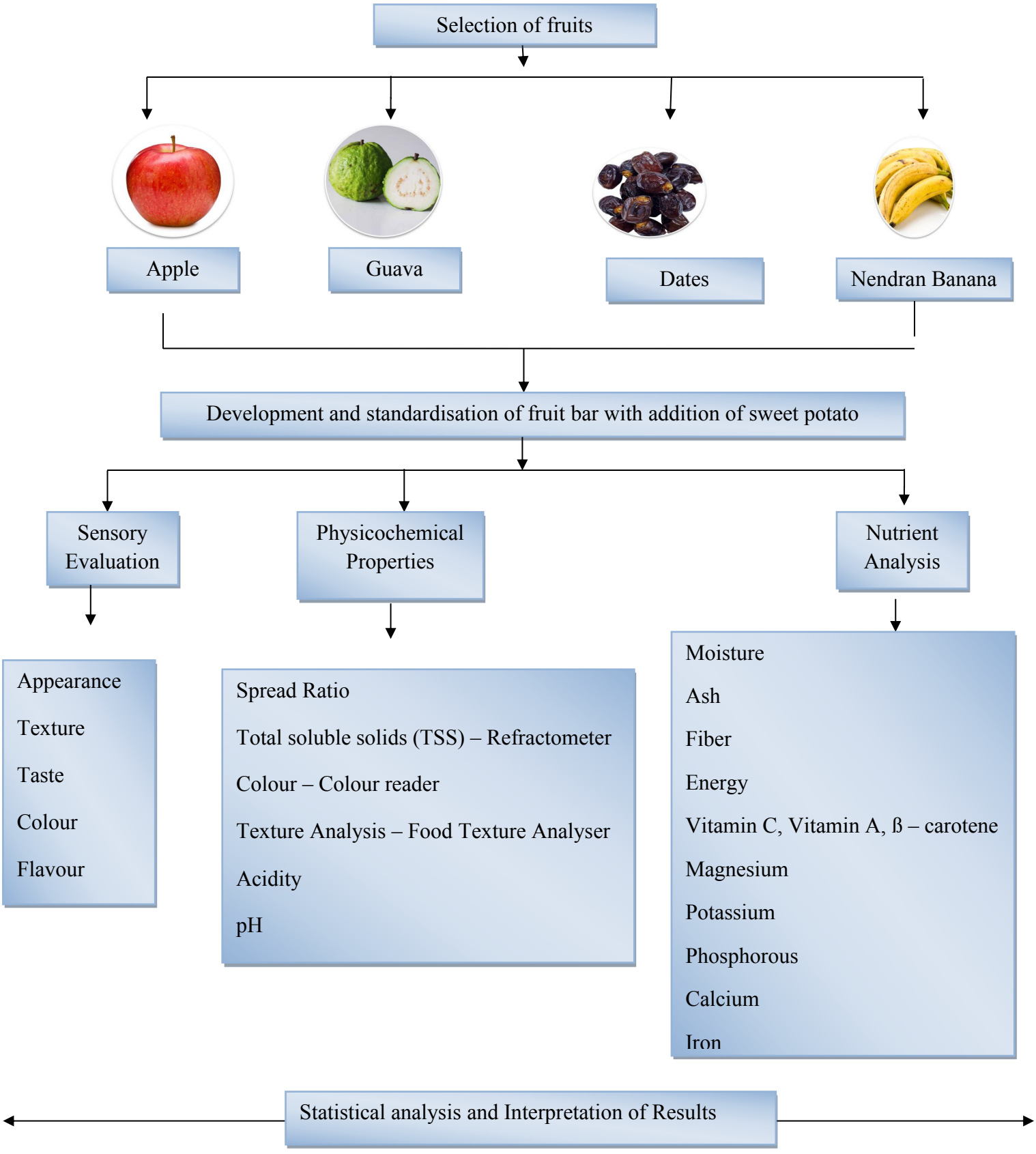


Figure 2

Research design

RESULTS AND DISCUSSION

IV. RESULTS AND DISCUSSION

The Results and Discussion pertaining to the study **"Development of Fruit Bar Rich in Beta Carotene and Vitamin C"** is presented under the following sub-headings:

A. Development and standardization of fruit bars
B. Sensory characteristics of the fruit bars
C. Physicochemical properties of the fruit bars
D. Nutrient content of the fruit bars

A. Development and standardization of fruit bars

The fruit bar was developed using sweet potato and respective fruit. The best method was standardized after trying different methods of preparation of fruit bar. The best method of preparation of fruit bar was identified and variation was prepared. Time taken for drying each fruit bar is recorded and presented in Figure 3. The temperature for drying ranged between 34 – 36°C. The fruit bars were allowed to dry in sunlight by covering using a thin cloth. The fruit bar on drying reached a sheet like appearance. The moisture present in the fruit bar was removed and also enhanced the appearance of the fruit bar. It can be inferred that sweet potato – nendran fruit bar took maximum of 12 hours, sweet potato – guava fruit bar took 8 hours, sweet potato – apple fruit bar took 6 hours and sweet potato - dates fruit bar took 3 hours to dry. This represents the moisture content as present in the product. Figure 3 represents the drying time for fruit bars.

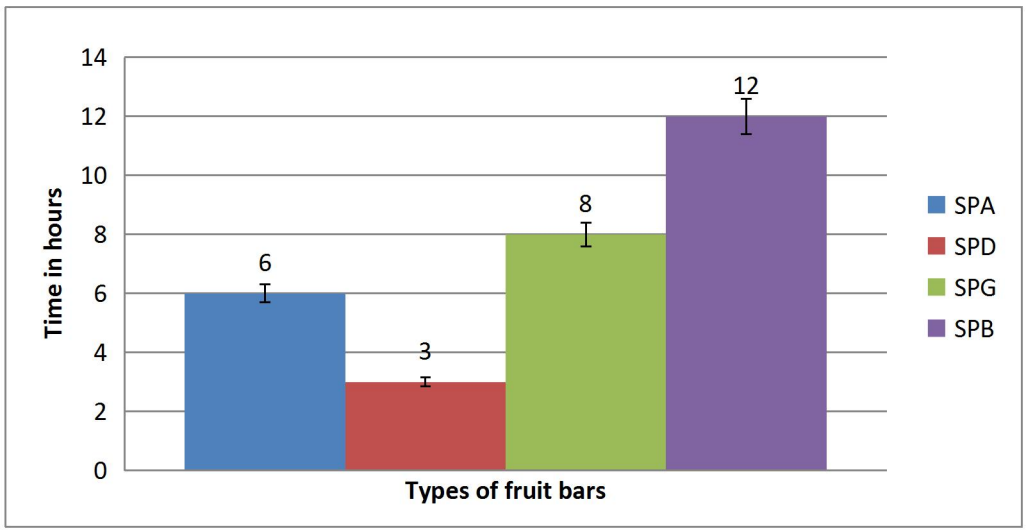


Figure 3

Time taken for drying the fruit bar

B. Sensory characteristics of the fruit bars

Sensory evaluation is a quantitative discipline that collects numerical data to discover particular correlations between product attributes and human perception (Lawless and Heymann, 1998). Human observer's data is frequently highly varied, and human panels are by definition a heterogeneous instrument for data creation. Statistics are used to examine evaluation data to determine whether the association observed between product attributes and sensory responses is likely to be true and not just the consequence of uncontrolled variance in responses (Lawless and Heymann, 1998). Sensory evaluation, like other analytical test processes, is concerned with precision, accuracy, sensitivity, and avoiding false positive results.

Four fruit bars were developed by combining sweet potato with apple, dates, guava and nendran banana separately. Mango fruit bar was kept as standard and four fruit bars were standardized along with three variations I, II, III. Variation I (SPA1) contains 150 g of apple, 100 g of sweet potato, 0.8 g agar agar and 6g of jaggery; variation II i.e, SPA2 contains 100 g of sweet potato, 150 g of apple and 6 g of jaggery; variation III i.e, SPA3 contains 100 g of sweet potato; 100 g of apple and 6 g of jaggery. In above variations apple was replaced with dates, guava and nendran banana. Variations of dates are mentioned as SPD1, SPD2, SPD3; variations of guava are mentioned as SPG1, SPG2, SPG3; variation of nendran banana is known as SPB1, SPB2, SPB3. Variations were compared with the standard and the results were interpreted. Table II denotes the variation codes of the fruit bar.

TABLE II

VARIATION CODES OF FRUIT BAR

Fruit bar - Standard	Variation 1	Variation 2	Variation3
Sweet potato – apple fruit bar (SPA)	SPA1	SPA2	SPA3
Sweet potato – dates fruit bar (SPD)	SPD1	SPD2	SPD3
Sweet potato –guava fruit bar (SPG)	SPG1	SPG2	SPG3
Sweet potato – nendran banana fruit bar (SPB)	SPB1	SPB2	SPB3

Sensory scores of sweet potato - apple fruit bar

Table III and Figure 4 represent the sensory evaluation of the sweet potato - apple fruit bar.

TABLE III

SENSORY EVALUATION OF SWEET POTATO – APPLE FRUIT BAR

N= 30

Criteria	Standard	SPA1	SPA2	SPA3
Appearance	8.93± 0.24	8.74 ± 0.44	8.09 ± 0.87	7.83 ± 1.09
Colour	8.70 ± 0.64	8.25 ± 0.50	7.64 ± 0.70	7.51 ± 0.76
Flavour	8.90 ± 0.30	8.70 ± 0.46	7.70 ± 0.97	7.38 ± 0.88
Texture	8.96 ± 0.17	8.70 ± 0.03	7.45 ± 0.72	7.19 ± 1.07
Taste	8.83 ± 0.37	8.77 ± 0.22	7.38 ± 0.76	7.12 ± 0.95
Overall acceptability	8.38 ± 0.76	8.16 ± 0.20	7.80 ± 0.60	7.19 ± 0.60
F value Standard vs Variation		2.316^{NS}	1.854^{NS}	0.554^{NS}

^{NS} - Not Significant

Sensory evaluation of the sweet potato - apple fruit bar revealed that the mean values for appearance for standard was 8.93which was the highest, followed by SPA1 with 8.74; SPA2 with 8.09 and SPA3 with 7.83. The mean values for colour were 8.70 for standard, 8.25 for SPA1, 7.64 for SPA2 and 7.51 for SPA3. The mean values obtained for flavour ranged between 7.38 to 8.90, the maximum score obtained for standard with the mean value of 8.90, followed by SPA1 with 8.70, SPA2 with 7.70 and SPA3 with 7.38. With regard to texture, standard showed the best result with a mean value of 8.96 followed by SPA1 with 8.70, SPA2 with 7.45 and SPA3 with 7.19. The taste of the standard scored maximum mean value of 8.83 followed by 8.77, 7.38 and 7.12 for SPA1, SPA2 and SPA3 respectively. The overall acceptability of sweet potato - apple fruit bar revealed that SPA1 had a maximum mean score of 8.16 and was comparable with the standard of value 8.38. This was followed by SPA2 and SPA3 with mean scores 7.80 and 7.19 respectively. The three

variations did not show any significant difference in the overall acceptability statistically when compared with the standard.

Sensory scores of sweet potato – dates fruit bar

Table IV and Figure 5 posturizes the sensory evaluation of sweet potato – dates fruit bar.

TABLE IV

SENSORY EVALUATION OF SWEET POTATO - DATES FRUIT BAR

N=30

Criteria	Standard	SPD1	SPD2	SPD3
Appearance	8.80 ± 0.40	8.51± 0.75	7.90 ± 0.90	7.64 ± 0.87
Colour	8.74 ± 0.19	8.61± 0.60	7.67± 0.65	7.45 ± 0.88
Flavour	8.90± 0.30	8.67± 0.81	7.58± 0.80	7.35 ± 1.19
Texture	8.51 ± 0.76	8.22± 0.86	7.26 ± 0.90	7.48 ± 0.81
Taste	8.80 ± 0.47	8.61± 0.65	7.54± 0.72	7.38 ± 0.61
Overall acceptability	8.90 ± 0.30	8.35± 0.93	7.48 ± 0.62	7.41 ± 0.76
F value Standard vs Variation		2.101^{NS}	1.975^{NS}	0.557^{NS}

^{NS} – Not significant

From Table IV, it was found that the appearance of the sweet potato - dates fruit bar among standard, SPD1, SPD2 and SPD3; standard scored the best result with mean values of 8.80, SPD3 scoring a decreased score of 7.64, while SPD1 and SPD2 showed mean values of 8.51 and 7.90. In terms of colour, standard and three variations got mean scores from 7.45 to 8.74. SPD1, SPD2, SPD3 had mean values of 8.61, 7.67, 7.45 respectively. The maximum mean score for colour was for standard with 8.74 followed by SPD1, SPD2, SPD3 with values of 8.61, 7.67, 7.45. The mean scores obtained for flavour ranged from 7.35 to 8.90, the minimum score 7.35 for SPD3, 7.58 for SPD2 and 8.67 for SPD1 and 8.90 for standard. Regarding texture, mean scores of standard showed a value of 8.51, SPD1 and SPD2 with 8.22, 7.26 and SPD3 with 7.48. Taste contributed mean scores from 7.38 to 8.80.The maximum mean value obtained

for standard was 8.80 followed by SPD1 with 8.61, SPD2 with 7.54 and SPD3 with 7.38. The mean overall acceptability score was 8.90 for standard; 8.35 for SPD1; 7.48 for SPD2 and 7.41 for SPD3 respectively. The F values were for SPDI, SPD2 and SPD3 are 2.101, 1.975, 0.557 respectively. The results implied that the variations were not significant statistically.

Sensory scores of sweet potato – guava fruit bar

Table V and Figure 6 represents the sensory evaluation of sweet potato - guava fruit bar.

TABLE – V

SENSORY EVALUATION OF SWEET POTATO – GUAVA FRUIT BAR

N=30

Criteria	Standard	SPG1	SPG2	SPG3
Appearance	8.96 ± 0.17	8.61 ± 0.76	7.96± 0.78	7.70 ± 0.90
Colour	8.74 ± 0.57	8.35 ± 0.60	7.96 ± 0.82	7.83 ± 0.82
Flavour	8.80 ± 0.60	8.64 ± 0.60	7.61 ± 1.03	7.41 ± 1.02
Texture	8.74 ± 0.57	8.58 ± 0.62	7.54 ± 0.83	7.41 ± 0.80
Taste	8.83 ± 0.52	8.22 ± 0.88	7.80 ± 0.77	7.58± 0.99
Overall acceptability	8.96 ± 0.17	8.77 ± 0.42	7.67 ± 0.77	7.45 ± 0.76
F value Standard vs Variation		1.635^{NS}	1.102^{NS}	0.785^{NS}

^{NS} – Not significant

From Table V, it is clear that the appearance of standard was maximum with mean value of 8.96 followed by SPG1 with 8.61, SPG2 with 7.96 and SPG3 with 7.70 for sweet potato - guava fruit bar. Colour contributed mean scores from 7.83 to 8.74. The maximum mean scores for colour obtained for standard was 8.74 followed by 8.35, 7.96 and 7.83 for SPG1, SPG2 and SPG3 respectively. In terms of flavour and texture, standard got mean value of 8.80 and 8.74 respectively, SPG1 got 8.64 and 8.58 respectively, SPG2 got 7.61 and 7.54 respectively and SPG3 got 7.41 in both respectively. The taste of the standard, SPG1, SPG2 and SPG3 secured a mean value

of 8.83, 8.22, 7.80 and 7.58 correspondingly. Overall acceptability of standard was 8.96, SPG1 was 8.77, SPG2 was 7.67 and SPG3 was 7.45 respectively. The overall mean acceptability was analyzed statistically using F test comparing standards with SPG1, SPG2 and SPG3. The F values were for SPGI, SPG2 and SPG3 are 1.635, 1.102, 0.785 respectively. The results implied that the variations were not significant statistically.

Sensory scores of sweet potato – nendran banana fruit bar

Table VI and Figure 7 reveals the sensory evaluation of sweet potato – nendran banana fruit bar.

TABLE – VI

SENSORY EVALUATION OF SWEET POTATO – NENDRAN BANANA FRUIT BAR

N=30

Criteria	Standard	SPB1	SPB2	SPB3
Appearance	8.93 ± 0.24	8.35 ± 0.91	7.96 ± 0.73	7.87 ± 0.88
Colour	8.74 ± 0.51	8.09 ± 0.74	7.61 ± 0.65	7.19 ± 0.60
Flavour	8.48 ± 0.67	8.25 ± 0.89	7.90 ± 0.89	7.35 ± 0.55
Texture	8.35 ± 0.79	8.12 ± 0.95	7.61 ± 0.79	7.29 ± 0.64
Taste	8.41 ± 0.67	8.22 ± 0.95	7.70 ± 0.77	7.64 ± 0.60
Overall acceptability	8.67 ± 0.54	8.38 ± 0.88	7.67 ± 0.69	7.54 ± 0.80
F value Standard vs Variation		0.054^{NS}	1.325^{NS}	0.026^{NS}

^{NS} – Not significant

Table VI and Figure 7 shows the results of sensory evaluation of sweet potato - nendran banana fruit bar. In terms of appearance, standard scored best with a mean score of 8.93 followed by SPB1 with 8.35, SPB2 with 7.96 and SPB3 with 7.87. In terms of colour, SPB3 had minimum score of 7.19 followed by SPB2 with 7.61, SPB1 with 8.09 and standard with 8.74. The mean scores obtained for the flavour in sweet potato – nendran fruit bar ranged from 7.35 to 8.48, the maximum obtained by standard

with a mean of 8.48 followed by 8.25, 7.90 and 7.35 for SPB1, SPB2 and SPB3 respectively. Regarding texture, mean scores of standard showed a maximum value of 8.35 followed by SPB1 with 8.12, SPB2 with 7.61 and SPB3 with 7.29 respectively. Taste is an important attribute. Taste contributes mean scores from 7.64 to 8.41 and maximum being in standard with 8.41 followed by SPB1 with 8.22, SPB2 with 7.70 and SPB3 with 7.64. In terms of overall acceptability, standard obtained 8.67 followed by SPB1 with 8.38 mean score; SPB2 with 7.67 and SPB3 with 7.54 respectively. The overall acceptability was analyzed statistically using F test comparing standards with SPB1, SPB2 and SPB3. The F values were for SPB1, SPB2 and SPB3 are 0.054, 1.325 and 0.026 respectively. The results revealed that the variations are not significant statistically. Comparing variations in fruit bar with standard showed that variation I scored the maximum values in terms of appearance, colour, flavour, texture, taste and overall acceptability for all the four fruit bars which was prepared using apple, dates, guava and nendran banana in combination with sweet potato. Hence the physiochemical properties and nutrient contents was analyzed for variation I (SPA1, SPD1, SPG1, SPB1) of fruit bars.

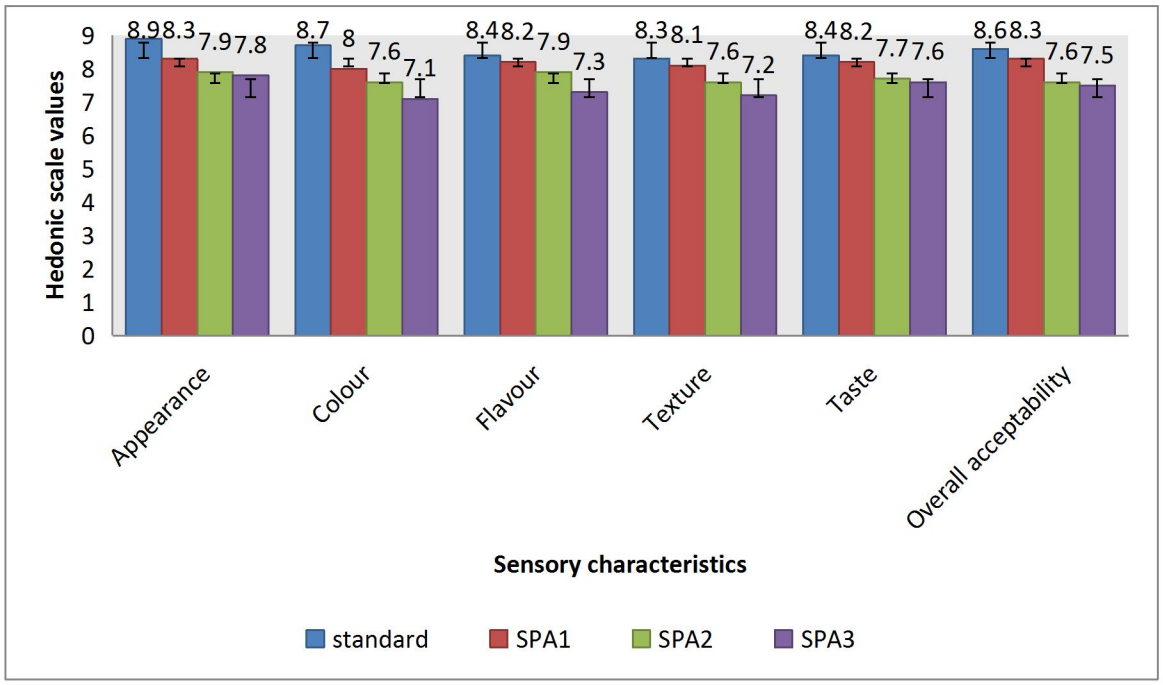


Figure 4
Sensory scores of sweet potato - apple fruit bar

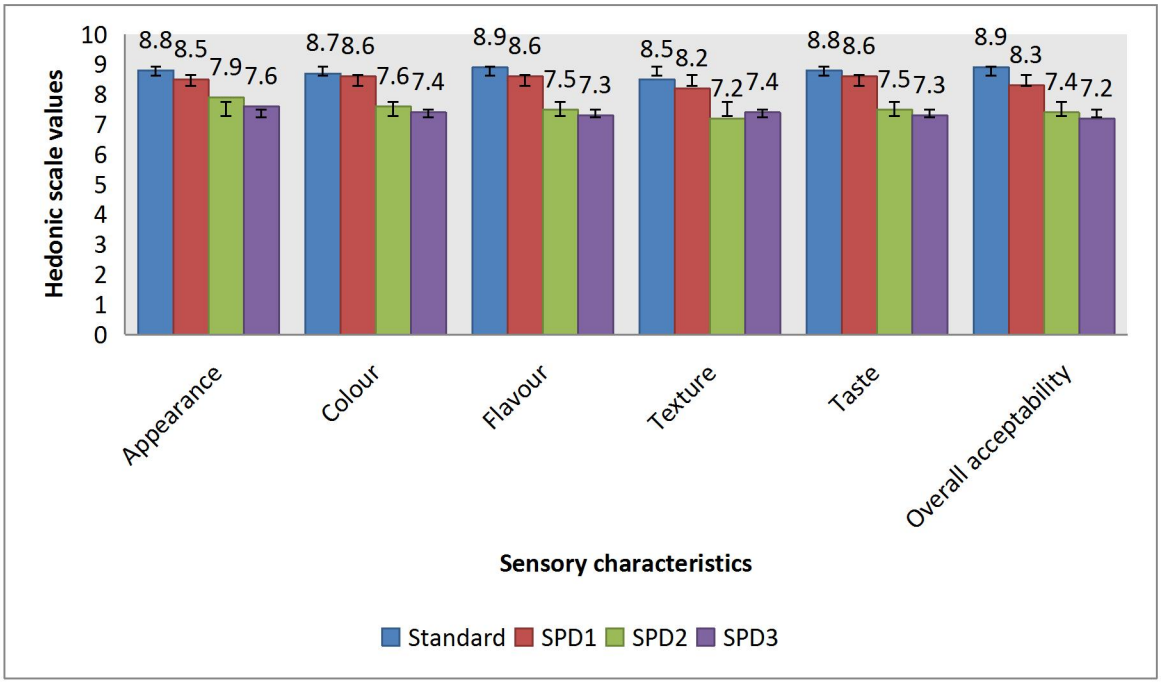


Figure 5
Sensory scores of sweet potato - dates fruit bar

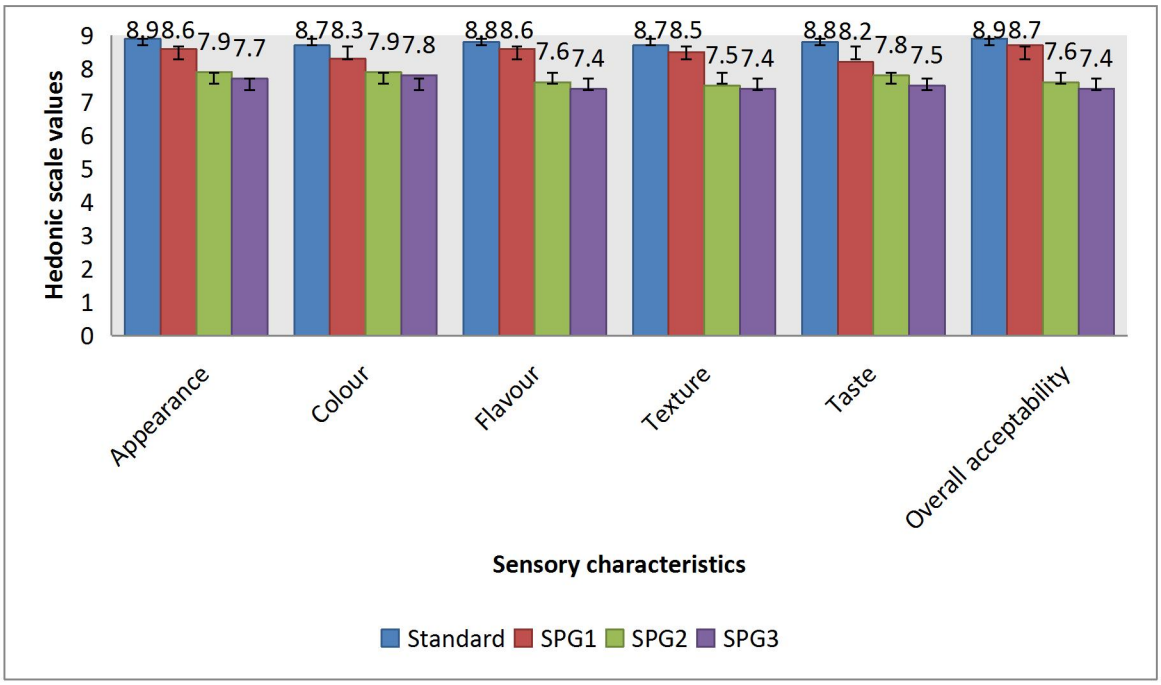


Figure 6

Sensory scores of sweet potato - guava fruit bar

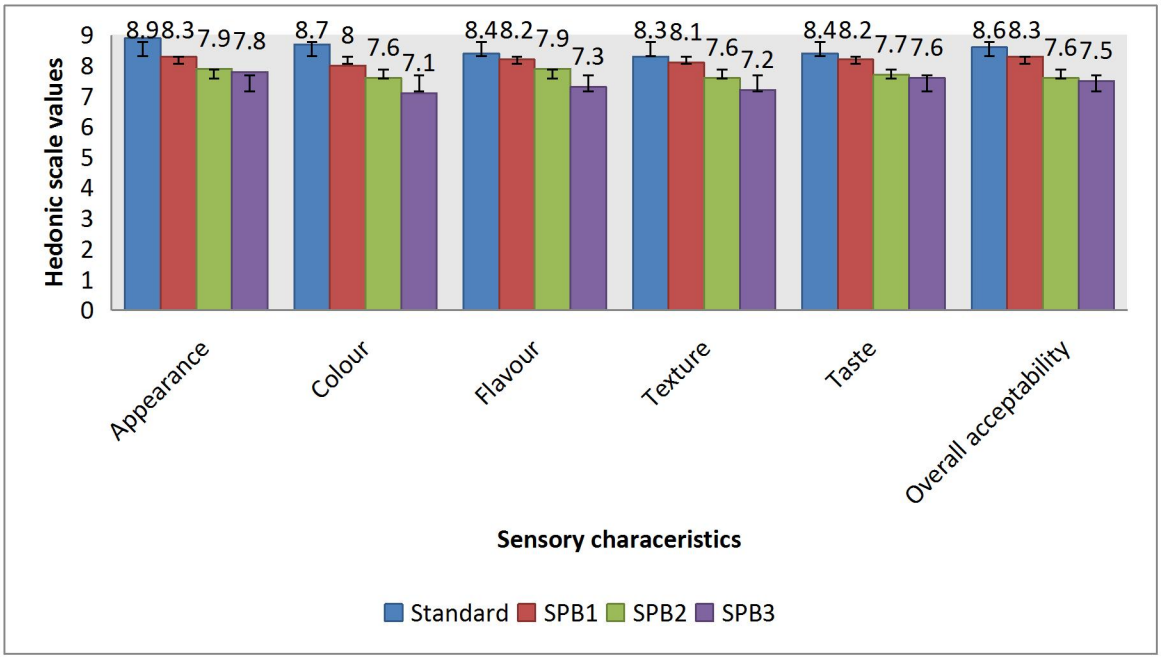


Figure 7

Sensory scores of sweet potato – nendran fruit bar

C. Physicochemical properties of the fruit bars

Physicochemical properties play an important role in the quality of food products due to their significant impact on bioactive potential and sensory attributes. Biological raw materials have inherent physicochemical properties that can be altered during processing, resulting in changes within or specific functions of the resulting food products. The modification of physicochemical properties of biological materials includes structural changes and changes in chemical composition caused by external factors such as temperature, pressure, and a variety of treatments such as microwaving or chemical fortification. Variation I was highly accepted by the panel members. Hence the physicochemical properties of fruit bars namely SPA1, SPD1, SPG1 and SPB1 was evaluated and is presented in Table VII.

TABLE VII

PHYSICOCHEMICAL PROPERTIES OF FRUIT BARS

Fruit bar	Spread Ratio (%)	Total Soluble Solids (%)	Colour (L*a*b)	Acidity (%)	pH	Reducing sugar (mg/g)
SPA1	12.88±0.26	9.20 ± 0.03	54.05*16.62*45.69	0.812 ± 0.26	4.5	39.05 ± 0.64
SPD1	11.45±0.32	11.23±0.25	63.02*14.66*35.21	0.958±0.46	2.7	44.06±0.12
SPG1	12.25±0.61	7.80±0.56	56.02*12.98*32.54	0.704±0.09	3.8	42.36±0.11
SPB1	10.70±0.26	10.08±0.62	59.03*14.88*36.02	0.583±0.09	6.3	56.09±0.33

Spread ratio of the fruit bars

Spread ratio is used to measure the quality of fruit bars. In terms of spread ratio SPA1 scored the best with a mean score of 12.88% followed by SPG1 with 12.25%, SPD1 with 11.45% and SPB1 with 10.7%. Spread ratio of SPB1 is low when compared to the SPA1, SPD1, SPG1 because nendran banana has more starch, less water and the pulp is used directly in the preparation of fruit bar. Due to its high solid particles, SPD1 had thick consistency on comparing with SPA1, SPD1 and SPG1. Apple has high fiber and water than dates, guava and banana, because of the high water content SPA1

had easy spread ratio (12.88 %) than other three fruits and fiber contributes to the stable texture and consistency. Fruit bars with thick consistency have low spread ratio and fruit bars with watery consistency have high spread ratio. Spread ratio of cactus pear fruit bar was found to be 15.61% (Maryna *et al.,* 2014). This value is nearest to the values determined in the present study.

Total soluble solids of the fruit bars

Total soluble solids play an important role in fruit maturation and the acceptance of rich nutrients. In terms of total soluble solids, as measured with refractometerSPG1 had minimum score of 7.80% followed by SPA1 with 9.2%, SPB1 with 10.08% and SPD1 with 11.23%. Guava is less in sweet when compared to apple, dates and nendran banana, hence the TSS of SPG1 is lower (7.80%) than other three fruits. Dates are high in fructose, and during processing dates lost their moisture which makes them more concentrated, so the TSS of SPD1 is higher (11.23%) than SPA1, SPG1 and SPB1. Apple and banana have high fructose than guava, and better moisture than dates. Thus the TSS of SPA1 (9.20%) and SPB1 (10.08%) is higher than guava and less than dates. The TSS content of the fruit is typically determined by determining the degree Brix of the fruit. The TSS, or sugar content, of a fruit measures and includes its carbohydrates, organic acids, proteins, fats, and minerals. It accounts for 10-20% of the fresh weight of the fruit and increases as the fruit matures to produce a less acidic, sweeter fruit (Natalia *et al.,* 2012).

Colour of the fruit bars

Colour determines the palatability of the food. Colour of the fruit bar were measured in L*a*b where L* represents black or white, a* represents red or green and b* represents yellow or green. Colour values of SPA1, SPD1, SPG1 and SPB1 are 54.05*16.62*45.69, 63.02*14.66*35.21, 56.02*12.98*32.54, 59.03*14.88*36.02 respectively. Colour of the fruit generally dominates the colour of the fruit bar. Apple, guava and banana are white in colour but the extract of sweet potato turns brown due to their reaction of iron with atmospheric oxygen. As a result sweet potato dominates the colour in all four fruit bars. Sunlight also affects the colour of the fruit bar as all the bars were sun dried. Before drying SPB1 which was mild yellow in colour turned to a tint of yellow shade after drying. This is due to the loss in moisture content of the fruit bar which

enhances the storage period. SPD1 is more dark than SPA1, SPG1 and SPB1, because dates itself is brown in colour. Due to the browning reaction, apple juice turned mild brown and when combined with sweet potato extract in preparation of fruit bar, colour changed further. SPA1 had mild reddish brown colour and SPD1 had dark brown colour. As guava was processed along with peel the fruit bar had shade of olive green. SPG1 had pale green colour and SPB1 had mild yellow colour. Colour value L, a, b of SPA1, SPD1, SPG1 and SPB1 represents that all the four fruit bars were more inclined towards black colour with a shade of red and yellow colour.

Acidity of the fruit bars

Almost all fruits are acidic due to their high sugar content. The mean scores obtained for the acidity of fruit bars ranged from 0.58% to 0.95%, the maximum value was obtained by SPD1 with a mean value of 0.95% followed by 0.81%, 0.70% and 0.58% for SPA1, SPG1, SPB1 respectively. High acidity (0.958%) in SPD1 is due to the high sugar content. Guava and apple are high in acid content particularly due to the presence of malic and citric acid. Nendran banana is more in sweet but less in acid content. Hence obtained low value of 0.58% when compared with other fruit bars. During the cooking process, acid aids in the extraction of pectin from the fruit. This helps in the formation of a gel. This will not occur unless the fruit is fairly acidic. The acidity of different samples ranges from 0.64-0.32 %, and the ascorbic acid content of different fruit bars increases as the guava concentration in the fruit bars increases (Aanchal *et al.,* 2019). The range of acidity obtained was similar to the above study.

pH of the fruit bars

pH is a measure of hydrogen ion concentration, which indicates whether a solution is acidic or alkaline. The pH scale is typically 0 to 14. Foods with a pH above 7 are considered alkaline, per the United States Environmental Protection Agency (EPA), whereas those that are below 7 are acidic. Lower the pH, the higher the level of acidity. Regarding pH, mean scores of SPB1 showed a maximum value of 6.3 followed by SPA1 with 4.5, SPB1 with 3.8 and SPD1 with 2.7 respectively. The pH of SPD1 is low as dates are sweeter, followed by SPG1 and SPA1 which contains acid in respective fruit. Nendran banana is sweet, and has high (6.3) pH while comparing other three fruits. Fruits with high acidity level help to actually lower blood acidity because they contain

alkaline-forming compounds. Fruits increase blood alkalinity and help to prevent calcium loss and promote bone health.

Reducing sugar of the fruit bars

A reducing sugar is any sugar that acts as a reducing agent because it contains either an aldehyde group (-CHO) or a ketone group (-CO-). Reducing sugar content contributes mean scores from 56.09 to 39.05 and maximum being in SPB1 with 56.09mg/g followed by SPD1 with 44.06mg/g, SPG1 with 42.36mg/g and SPA1 with 39.05mg/g. In terms of reducing sugar content SPB1 scored the maximum (56.09mg/g) due to its high carbohydrate content. Reducing sugar content carbohydrate or natural sugar and its percentage increases over ripening period. Hence in the present study sweet potato - banana fruit bar had high (56.09mg/g) reducing sugar. At low pH, sugars behave differently. In basic aqueous solution, it can be oxidised by a weak oxidising agent such as tollen's reagent. They produce one or more compounds containing an aldehyde or ketone group in aqueous solution. They cause other substances to be reduced after oxidation. Maltose, which contains a hemiacetal group, for example, reacts with water to form an open-chain containing an aldehyde group. Furthermore, the majority of these are monosaccharides such as glucose, fructose, and galactose, or disaccharides such as lactose and maltose (Paradkat *et al.,* 2013).

Texture of fruit bars

Texture is a major determinant of food acceptance. Table VIII and Figure 8 indicates the texture of the fruit bar.

TABLE VIII

TEXTURE OF FRUIT BARS

Fruit bar	Test mode	Speed	Test type	Hardness (N)	Adhesiveness (MPa)
SPA1	Texture	1mm/sec	Compression	12. 9928	0.01086
SPD1	Texture	1mm/sec	Compression	14.6234	0.01062
SPG1	Texture	1mm/sec	Compression	9.1091	0.01024
SPB1	Texture	1mm/sec	Compression	11.7526	0.01093

Hardness is a textural characteristic that is estimated during the first ingestion; strength is applied to the food product in an approximately linear manner and can be reproduced satisfactorily (Monaco *et al.,* 2008). SPD1 had more hardness of 14.62N followed by SPA1, SPB1 and SPG1 with the values of 12.99N, 11.75N, 9.10N respectively. SPD1 had more hardness than other three fruit bars. This may be due to the dense biopolymer network and reduced pore size. High springiness and larger pores made the SPA1 softer than SPD1, SPG1 and SPB1. SPD1 has biting consistency, glossy appearance and the texture was fine, not hard; SPA1 was glossy in texture, rubbery and had good sheeting than other fruit bars; SPB1 took time to chew as it had low moisture content and high in carbohydrates and solid particles; SPG1 had softer texture, not watery but easy to bite, opaque when compared to SPA1 and SPD1. Agar agar contributed to the perfect texture of prepared fruit bars.

The work required to remove food that adheres to the mouth (generally the palate) during the normal swallowing process is defined as adhesiveness, and cohesiveness is defined as the strength of internal bonds that make up the body of the food(Monaco *et al.,* 2008).The adhesiveness of the fruit bar ranged from 0.01024 to 0.01093MPa. SPB had the maximum adhesiveness with the value of 0.01093MPa, followed by 0.01086MPa, 0.01062MPa, 0.01024MPa for SPA1, SPD1, SPG1 respectively. Fruit bars were rubbery and stick to palate of mouth and relieved after passing the tongue through bottom of it and slowly got soluble in saliva.

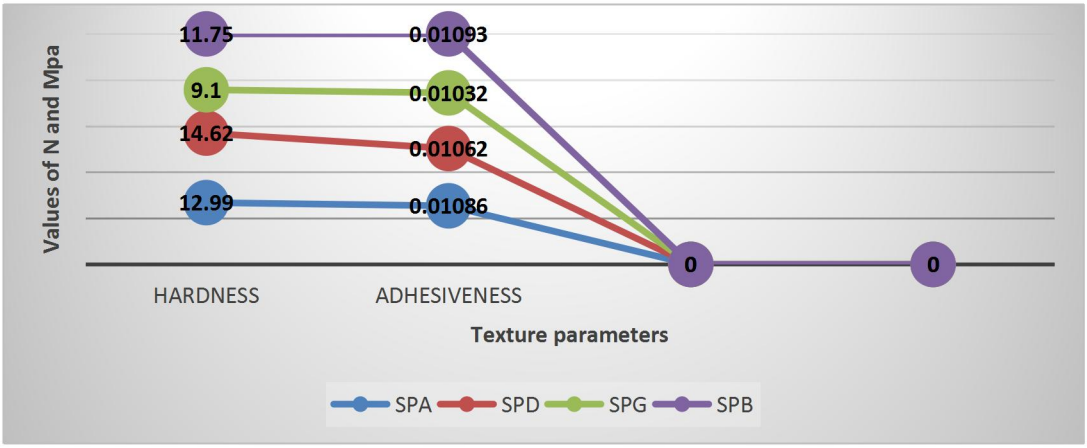


Figure 8

Texture of fruit bars

D. Nutrient content of the fruit bars

Table IX and Figure 9 represents the nutrient content of the fruit bars.

TABLE IX
NUTRIENT CONTENT OF FRUIT BARS

Nutrients	SPA1	SPD1	SPG1	SPB1
Moisture (%)	8.10 ± 0.16	5.40 ± 0.22	11.00 ± 0.12	**12.10 ± 1.2**
Ash (g)	**6.80 ± 0.71**	4.46 ± 0.34	5.43 ± 0.04	6.28 ± 0.25
Fiber (g)	**6.70± 0.01**	5.69 ± 1.2	5.90 ± 0.23	5.20± 0.2
Energy (kcal)	289 ± 10.2	**325 ± 14.87**	264 ± 12.34	314 ± 18.62
Vitamin C (mg)	5.10 ± 0.55	3.20 ± 0.2	**15.60 ± 0.18**	10.09 ± 0.85
Vitamin A (mg)	3.50 ± 0.8	2.90 ± 0.15	**4.20 ± 0.2**	3.26 ± 1.6
Beta Carotene (µg)	**32 .00± 8.4**	19.80 ± 0.28	12.10 ± 0.32	9.32 ± 0.87
Sodium (mg)	10.60± 2.32	6.41 ± 1.47	9.25 ± 0.38	**13.40 ± 1.1**
Magnesium (mg)	9.00 ± 0.43	8.00 ± 0.33	**19.00 ± 0.24**	11.26 ± 0.54
Potassium (mg)	419 ± 12.04	489 ± 14.32	522 ± 13.27	**581 ± 13.6**
Phosphorous (mg)	15 ± 2.37	12 ± 1.64	**32 ± 0.79**	23 ± 1.33
Calcium (mg)	**61 ± 3.2**	55 ± 2.47	25 ± 0.54	49.50 ± 2.1
Iron (mg)	2.70 ± 0.58	**5.20± 0.38**	1.10± 0.01	1.67 ± 0.03

Moisture

From Table IX, it is clear that the moisture of SPB was maximum with mean value of 12.10% followed by SPG1 with 11%, SPA1 with 8.10% and SPD1 with 5.40% fordeveloped fruit bars. A moisture range of 11 to 15% for guava bar and 10 to 15% for mango bar was found to be safe for product storage (Vijayanand *et al.,* 2000). The moisture content (11.00%) of SPG1 is almost similar to the value derived in the study. Higher the moisture content, lower will be the shelf life of the fruit bars. Hence the moisture content was removed by sun drying. Drying time of each fruit bar varied because of the different moisture content. Dried fruit bars do not stick to hand and teeth and easy to cut into desired shapes. If the fruit bar contains excess moisture, fungus will develop over and spoils the product.

Ash

The amount of inorganic noncombustible material in a sample is measured by its ash content.It is a component of proximate analysis for nutritional assessment. The first step in preparing a food sample for elemental analysis is ashing. In contrast to the ash left over from incomplete combustion, the residues after a sample is completely burned typically consist of oxides of the inorganic elements present in the original sample. Ash contributed mean scores from 4.4g to 6.8g. The maximum mean scores for ash obtained was, for SPA1 with 6.8g followed by 6.2g, 5.4g and 4.4g for SPB1, SPG1 and SPD1 respectively.

Fiber

Fiber acts as prebiotic in human metabolism. In terms of fiber, SPA1 had mean value of 6.7g, SPD1 had 5.6g, SPG1 had 5.9g and SPB1had 5.2g. Apples are known for their fiber content, thus SPA had more fiber than SPD1, SPG1 and SPB1. Green ripened guava utilized in preparation of fruit bar is good source of fiber and SPG1 had second most fiber content; followed by SPD1 with 5.69g. Fresh dates are found to be rich in fiber than dried dates. Banana was rich in carbohydrates and minerals than fiber, hence SPB1 scored the least with 5.2g of fiber.

Energy

In terms of energy SPD1 got the maximum mean value 325 kcal, followed by SPB1 with 314 kcal; SPA1 with 289kcal; SPG1 with 264kcal. Dates are high in sugar and carbohydrates and had higher energy value, hence SPD1 scored the highest in mean values of energy followed by SPB1, as nendran banana is also sweeter and rich source of carbohydrates. It is a dense fruit and sometimes replaces a whole meal when combined with milk. SPA1 ranged third in mean values of energy due to less carbohydrates and sugar of apple, while comparing with dates and nendran. SPG1 has the lowest value as guava is high in citric acid, less in sweet and low level of carbohydrates.

Vitamin C

Vitamin C helps in boosting immunity. Vitamin C of the SPA1, SPD1, SPG1, SPB1 secured a mean value of 5.1mg, 3.2 mg, 15.6mg, 10.09mg correspondingly. Vitamin C in dates is solubilised when soaked in water before grinding, so SPD1 had

less vitamin C. This vitamin is not heat stable and cannot withstand the temperature above 86°F and destroys when exposed to air. Daily intake of vitamin C for an individual is 40 mg. Loss of vitamin in fruit bar can be overcome by cooking the fruit or vegetable as fast as possible with less heat and small amount of water. As SPB1 took less time to cook than SPA1 and SPD1, it retained a vitamin C content of 10.09mg. Guava is generally high in vitamin C, hence even after exposing to heat for 5 minutes SPG1 still contains 15.6mg. After processing SPA1 retained 5.1mg of vitamin C.

Vitamin A

Vitamin A is a fat soluble vitamin and precursor of beta carotene. It mainly contributes to vision, immune system and reproduction. Vitamin A of SPA1 was 3.5mg, SPD1 was 2.9mg, SPG1 was 4.2mg and SPB1 was 3.26mg. Vitamin A of SPG1 is higher than SPD1, SPA1 and SPB1. The variation is due to the vitamin content of the fruit and loss of vitamins in processing. Vitamin A does not destroy easily in heat but readily oxidized in atmospheric oxygen. SPD1 has the less value of vitamin A as dates are already processed from fresh form to dried from and further undergoes processing in preparation of fruit bar.

Beta carotene

Beta carotene is a provitamin A carotenoid, which means it is easily converted by the body into vitamin A. It is an important flavonoid compound, has powerful antioxidant functions that help the body scavenge free radicals, limiting damage to cell membranes, DNA, and protein structures in the tissues. The mean scores obtained for the beta carotene of fruit bars ranged from 9µg to 32µg, the maximum obtained by SPA1 with a mean of 32µg followed by 19.8µg, 12.1µg, 9.3µg for SPD, SPG1, SPB1 respectively. The level of beta carotene obtained in fruit bars is not sufficient to meet daily requirements of beta carotene which is 10800µg per day. The loss of beta carotene can be prevented by using the fruit pulp without straining and reducing constant exposure to atmosphere. SPB1 has low beta carotene due to the reduction in cooking time. Beta carotene generally does not destroy during application of heat but it further increases due to the breakdown of plant cell walls. Degradation occurs in high humidity and high temperature. SPA1 has more beta carotene than SPD1, SPG1 and SPB1. The lower value of SPD1 is due to the poor beta carotene value of dates.

Sodium

Sodium controls blood pressure and regulates the functions of nerves and muscles. It regulates the total amount of water in the body, and sodium transmission into and out of individual cells is also important for critical body functions. Many bodily processes, particularly those in the brain, nervous system, and muscles, rely on electrical signals for communication. Regarding sodium, mean scores of SPB1 showed a maximum value of 13.40 mg followed by SPA1 with 10.60mg, SPG1 with 9.20mg and SPD1 with 6.40mg. SPB1 had the highest value as nendran banana is a great source of sodium. SPD1 scored the least due to less sodium content in dates. The values of SPA1 and SPG1 do not differ much as both fruits contain sodium to a significant level. Figure 10 represents the macro minerals in fruit bar.

Potassium

Potassium is an essential mineral for human body. It is essential to the body's normal functioning, aids in the maintenance of acidity and blood pressure and required for electrical signals to be transmitted from nerves to cells and vice versa. Potassium contributes mean scores from 581mg to 419mg and maximum being in SPB1 with 581mg followed by SPG1 with 522mg, SPD1 with 489mg and SPA1 with 419mg. SPB1 scored the best due to the enriched potassium in nendran banana. SPG1 has the second maximum potassium value as guava is enriched with potassium which makes it more available than SPD1 and SPA1. SPA1 scored the least because of low potassium level in apple.

Phosphorous

Phosphorus collaborates with calcium to aid in bone formation. For bone health, the right amount of calcium and phosphorus are required. Phosphorus is also important in the structure of nucleic acids and cell membranes. Phosphorous contributed mean scores from 12mg to 32mg. The maximum mean scores for phosphorous obtained for SPG1 with 32mg followed by 23mg, 15mg,12 mg for SPB1, SPA1 and SPD1 respectively. Guava is rich in phosphorous and SPG1 scored the maximum mean value; SPB1 scored the next highest value as nendran banana is rich source of minerals. SPA1 and SPD1 have low phosphorous level, as the fruits are not good sources of phosphorous.

Calcium

Calcium salts play an important role in bone and tooth development. Calcium ions are required for blood clotting and control nerve excitability by regulating membrane permeability; Calcium ions act as a cofactor or activator of certain enzymes. In terms of calcium, SPA1 got mean value of 61 mg, SPD1 got 55mg, SPG1 got 25mg and SPB1 got 49.5mg. Calcium content of the SPA1 was the highest when compared to SPD1, SPG1 and SPB1. The level of calcium depends upon the way of cooking of the product. SPD1 has good amount of calcium as it retains 55mg. As like phosphorous SPB1 is enriched with calcium. Heating reduces soluble calcium content because ionic calcium combines with phosphates or denatured protein converts to colloidal calcium form, thus SPG1 has less amount of calcium as it takes bit longer to reach desired consistency.

Iron

Iron contributed mean scores from 1.1mg to 5.2 mg. SPG1 got minimum mean value of 1.10 mg followed by SPB1 with 1.67 mg; SPA1 with 2.7mg and SPD1 with 5.2mg. SPD1 scored the maximum as dates are known for its iron content. SPA1 was the second highest as apple contain good amount of iron than guava and nendran banana. SPG1 scored the least, but guava contains more vitamin C that enhances the iron absorption in body.

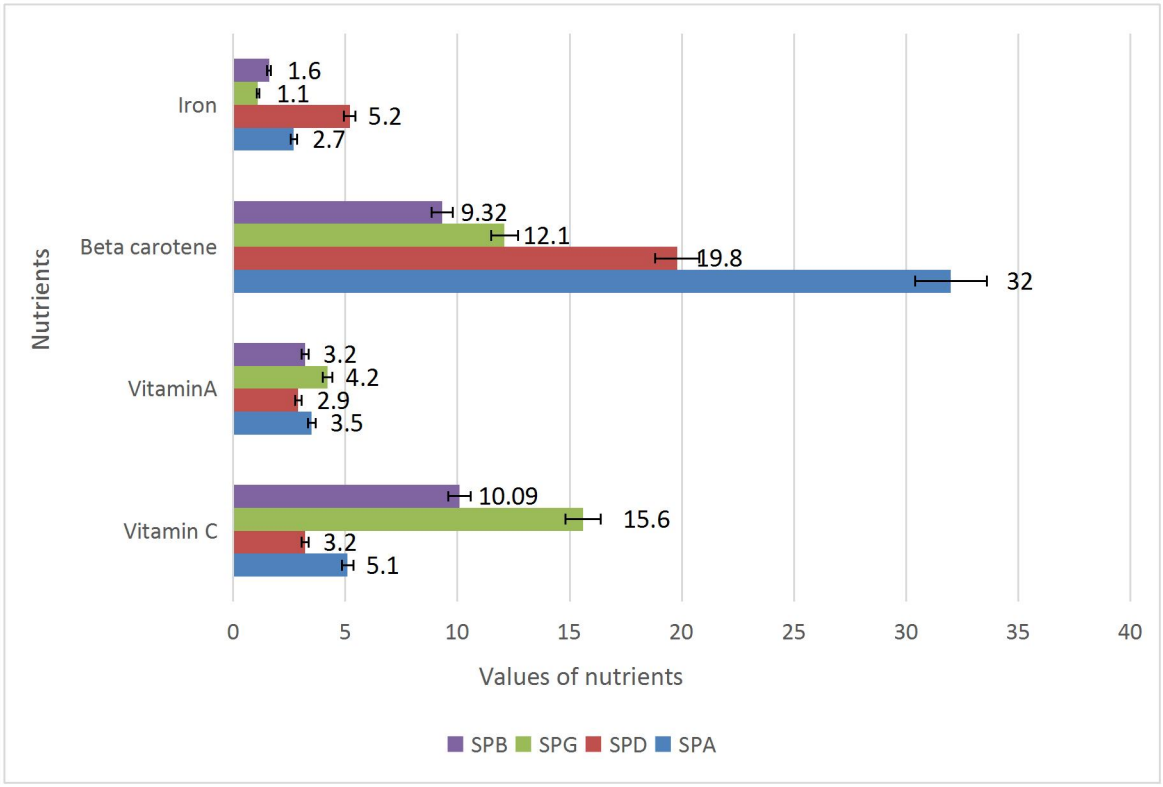


Figure 9
Nutrients in fruit bar

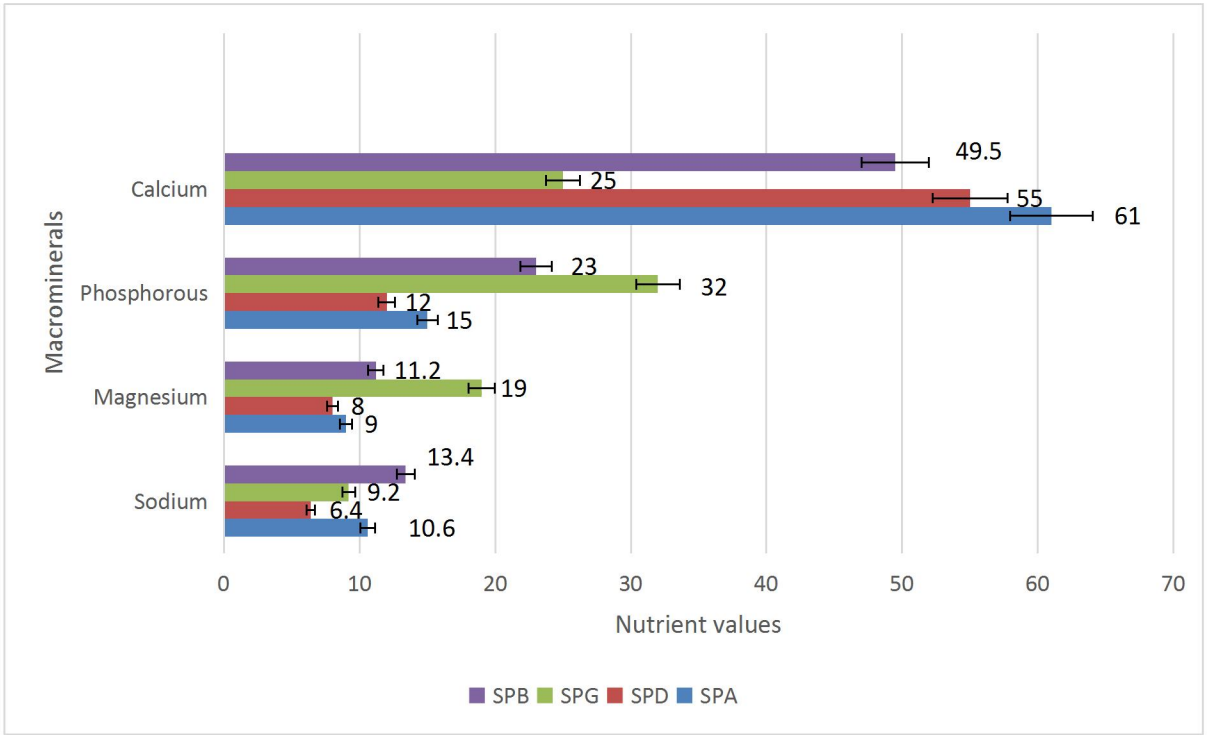


Figure 10
Macro minerals in fruit bars

SPA1 costs Rs.8, SPD1 costs Rs.5, SPG1 costs Rs.5 and SPB1 costs Rs.7. In sensory evaluation variation I scored the best for all fruit bars (SPA, SPD, SPG and SPB). Results of physiochemical properties indicate that SPA1 has higher spread ratio(12.88 %), SPD1 has highest TSS (11.23%) and acidity of SPD1 has higher value (0.958%) than SPA1, SPG1 and SPB1. SPB1 has more pH (6.3) than other three fruit bars. Colour value L, a, b SPA1 (54.05*16.62*45.69), SPD1 (63.02*14.66*35.21), SPG1 (56.02*12.98*32.54) and SPB1 (59.03*14.88*36.02) represents that all the four fruit bars were more inclined towards black colour with red and yellow colour. Reducing sugar of SPB1 is more (56.09mg/g) when compared to SPA1, SPG1 and SPD1. Results of texture reveal that SPD1 has more hardness (14.6234N) than other three fruit bars and adhesiveness of SPB1 is greater (0.01093Mpa) than SPA1, SPD1and SPG1.

Nutrient content of fruit bar reveals that moisture content is high (12.10 %) in SPB1, ash (6.80g) and fiber (6.70g) content is higher in SPA1 than SPD1, SPG1 and SPB1. Energy value of SPD1 is maximum (325kcal) among four fruit bars. SPG1 dominates the vitamin A (15.60 mg) and C (4.20 mg) content while comparing with other three fruit bars. SPA1 contributes to higher beta carotene (32 .00 µg) than SPD1, SPG1 and SPB1. Sodium content is high (13.40 mg) in SPB1 and magnesium is maximum (19.00mg) in SPB1. Potassium is high (581mg) in SPB1. SPG1 scored the maximum (32mg) in phosphorous and SPA1scored highest (61mg) for calcium. Iron content of SPD1 is greater (5.20mg) than SPA1, SPG1 and SPB1.

SUMMARY AND CONCLUSION

V. SUMMARY AND CONCLUSION

Fruits are good source of vitamins and minerals. Seasonal fruits are not available throughout the year and also have less shelf life. Fruits are processed in many forms to make it available all time. Some of the processed forms of fruits are squash, jam, jelly, concentrated beverages, candies, dried fruits, fruit bar, fruit preserves, canned fruits etc. Fruit bars generally do not require more processing and have better shelf life. Fruit bars are generally made using pulp or extract of the fruit and are rich in nutrients. They contain a variety of essential nutrients and vitamins, as well as enough protein and carbohydrates to keep the body running. Fruit bars contain real fruit or fruit juice. Gelled fruit matrices, dried gels or sponges, and extruders are examples of new trends in fruit bar processing. Pulp rich fruits like mango, banana, apple, grapes, papaya, tomato, apple are generally used in the preparation of fruit bar.

Sweet potato contain high amount of starch and pulp and also rich in beta carotene. Carotenoids in sweet potatoes might lower the risk for cancer.It is a staple food, high in fiber, calcium, magnesium, iron, potassium and phytochemicals. Sweet potatoes are a first-rate supply of fiber, in particular while devouring the skin.

Apple is rich in vitamin C, B1, B6, polyphenols and fiber. It also contains antioxidants like vitamin E which helps to protect the cells by reducing free radicals, vitamin B1 in apple supports growth and development and vitamin B6 is needed for protein metabolism.Because of their high fiber and water content, apples are particularly filling. Flavonoids in apples can help prevent heart disease by lowering blood pressure, lowering LDL cholesterol oxidation, and lowering atherosclerosis, or the buildup of plaque in arteries.

Dates are rich in vitamin C, potassium, magnesium and iron. Dates consists of protein, fat, crude fiber, minerals, various vitamins, tannins, and a variety of other components. Dates have a high nutritional value and can help humans meet their nutritional requirements.

Guava is a good source of vitamin C, calcium, potassium an iron. Botanically, guavas are berries.Guava is widely consumed and rich in phytochemicals with medicinal value. Guava is frequently included among super fruits due to its high nutritional value. Consumption of ripe guava fruit with peel reduced BMI and blood

pressure ($p<0.05$), whereas fasting blood glucose (FPG), total cholesterol, and triglycerides were significantly increased ($p<0.05$).

Nendran banana is rich in Vitamin A, C, B6 and potassium. Because of its high levels of vitamin A activity and sugars, the nendran banana is a good potential fruit that could be widely produced as a nutritional and energy food resource.People with diabetes can eat bananas, it is not recommended that they consume a large amount in one sitting.

The present study entitled **"Development of Fruit Bar Rich in Beta Carotene and Vitamin C"** was aimed at developing fruit bar of apple, dates, guava and nendran banana in combination with sweet potato and evaluation of sensory qualities, physicochemical properties and nutrients. Fruit bars were developed based on trial and error method. After carrying our trials using different methods, best method was identified to bring out variations.

Juice was extracted from 100g of sweet potato and 150g of fruit was grinded to obtain juice/pulp. In hot pan sweet potato extract was added and allowed to cook till raw flavour disappears and then juice/pulp of respective fruit was added and heated for 2 minutes. In another vessel 1g of agar agar was double boiled and added to the fruit mixture in liquid consistency. It is continuously stirred until became thick and then poured in greased plate to 2mm of thickness and allowed to sun dry.

The developed fruit bars were subjected to sensory evaluation by 30 semi – trained panel members along with standard and three different variations of respective fruits (SPA1, SPA2,SPA3, SPD1, SPD2, SPD3, SPG1, SPG2, SPG3, SPB1, SPB2, SPB3) with the help of score card (9 point hedonic scale). The evaluation was done in terms of the attributes like appearance, colour, flavour, texture, taste and overall acceptability of the fruit bars by rating from like extremely to dislike extremely in the 9 point hedonic scale rating.

The analysis of physicochemical properties includes spread ratio, total soluble solids, colour, texture, acidity, pH and reducing sugar content. Nutrient analysis of moisture, ash, fiber, energy, vitamin C, vitamin A, beta carotene, sodium, magnesium, potassium, phosphorous, calcium and iron were conducted.Only very few Indian studies are available in developing fruit bars in combination with sweet potato and keeping this

in mind, an attempt was made in the present study, entitled with the following objectives to:

- development and standardization of fruit bars using sweet potato and selected fruits
- carry out sensory evaluation of the developed fruit bars
- analyze the major nutrients and physiochemical properties of the fruit bars

The salient findings of the study are summarised below:

- ✓ Sensory evaluation of the **sweet potato - apple fruit bar** revealed that the mean values for appearance for standard was 8.93which was the highest, followed by SPA1 with 8.74; SPA2 with 8.09 and SPA3 with 7.83. The mean values for colour were 8.70 for standard, 8.25 for SPA1, 7.64 for SPA2 and 7.51 for SPA3. The mean values obtained for flavour ranged between 7.38 and 8.90, the maximum score obtained for standard with the mean value of 8.90, followed by SPA1 with 8.70, SPA2 with 7.70 and SPA3 with 7.38. With regard to texture, standard showed the best result with a mean value of 8.96 followed by SPA1 with 8.70, SPA2 with 7.45 and SPA3 with 7.19. The taste of the standard scored maximum mean value of 8.83 followed by 8.77, 7.38 and 7.12 for SPA1, SPA2 and SPA3 respectively. The overall acceptability of sweet potato - apple fruit bar revealed that SPA1 had a maximum mean score of 8.16 and was comparable with the standard of value 8.38. This was followed by SPA2 and SPA3 with mean scores 7.80 and 7.19 respectively. The three variations did not show any significant difference in the overall acceptability statistically when compared with the standard.
- ✓ Sensory evaluation of the **sweet potato - dates fruit bar** showed that, in terms of appearance standard scored the best result with mean values of 8.80, SPD3 scoring a decreased score of 7.64, while SPD1 and SPD2 showed mean values of 8.51 and 7.90. In terms of colour, standard and three variations got mean scores from 7.45 to 8.74. SPD1, SPD2, SPD3 had mean values of 8.61, 7.67, 7.45 respectively. The maximum mean score for colour was for standard with 8.74 followed by SPD1, SPD2, SPD3 with values of 8.61, 7.67, 7.45. The mean

scores obtained for flavour ranged from 7.35 to 8.90, the minimum score 7.35 for SPD3, 7.58 for SPD2 and 8.67 for SPD1 and 8.90 for standard. Regarding texture, mean scores of standard showed a value of 8.51, SPD1 and SPD2 with 8.22, 7.26 and SPD3 with 7.48. Taste contributed mean scores from 7.38 to 8.80.The maximum mean value obtained for standard was 8.80 followed by SPD1 with 8.61, SPD2 with 7.54 and SPD3 with 7.38. The mean overall acceptability score was 8.90 for standard; 8.35 for SPD1; 7.48 for SPD2 and 7.41 for SPD3 respectively. The F values were for SPDI, SPD2 and SPD3 are 2.101, 1.975, 0.557respectively. The results implied that the variations were not significant statistically.

- ✓ Sensory evaluation of the **sweet potato - guava fruit bar** showed that, in terms of appearance standard scored best with a mean score of 8.93 followed by SPB1 with 8.35, SPB2 with 7.96 and SPB3 with 7.87. In terms of colour, SPB3 had minimum score of 7.19 followed by SPB2 with 7.61, SPB1 with 8.09 and standard with 8.74. The mean scores obtained for the flavour in sweet potato - nendran fruit bar ranged from 7.35 to 8.48, the maximum obtained by standard with a mean of 8.48 followed by 8.25, 7.90 and 7.35 for SPB1, SPB2 and SPB3 respectively. Regarding texture, mean scores of standard showed a maximum value of 8.35 followed by SPB1 with 8.12, SPB2 with 7.61 and SPB3 with 7.29 respectively. Taste is an important attribute. Taste contributes mean scores from 7.64 to 8.41 and maximum being in standard with 8.41 followed by SPB1 with 8.22, SPB2 with 7.70 and SPB3 with 7.64. In terms of overall acceptability, standard obtained 8.67 followed by SPB1 with 8.38 mean score; SPB2 with 7.67 and SPB3 with 7.54 respectively. The overall acceptability was analyzed statistically using F test comparing standards with SPB1, SPB2 and SPB3.
- ✓ Sensory evaluation of **sweet potato - nendran banana fruit bar** showed that, in terms of appearance, standard scored best with a mean score of 8.93 followed by SPB1 with 8.35, SPB2 with 7.96 and SPB3 with 7.87. In terms of colour, SPB3 had minimum score of 7.19 followed by SPB2 with 7.61, SPB1 with 8.09 and standard with 8.74. The mean scores obtained for the flavour in nendran

sweet potato fruit bar ranged from 7.35 to 8.48, the maximum obtained by standard with a mean of 8.48 followed by 8.25, 7.90 and 7.35 for SPB1, SPB2 and SPB3 respectively. Regarding texture, mean scores of standard showed a maximum value of 8.35 followed by SPB1 with 8.12, SPB2 with 7.61 and SPB3 with 7.29 respectively. Taste is an important attribute. Taste contributes mean scores from 7.64 to 8.41 and maximum being in standard with 8.41 followed by SPB1 with 8.22, SPB2 with 7.70 and SPB3 with 7.64. In terms of overall acceptability, standard obtained 8.67 followed by SPB1 with 8.38 mean score; SPB2 with 7.67 and SPB3 with 7.54 respectively. The overall acceptability was analyzed statistically using F test comparing standards with SPB1, SPB2 and SPB3. The F values were for SPB1, SPB2 and SPB3 are 0.054, 1.325 and 0.026 respectively. The results revealed that the variations are not significant statistically.

- ✓ Comparing variations of the fruit bar with standard showed that **variation I** scored the maximum values in terms of appearance, colour, flavour, texture, taste and overall acceptability for all the four fruit bars which was prepared using apple, dates, guava and nendran in combination with sweet potato.
- ✓ **Sweet potato - apple fruit bar**- SPA1 has 12.88% spread ratio, 9.20% total soluble solids, 54.05*16.62*45.69 of L*a*b which indicates colour, 0.812% of acidity, pH of 4.5 and 39.05mg/g of reducing sugar. Hardness of SPA1 was 12.99 N and adhesiveness was 0.01086 Mpa. Moisture of SPA1 was 8.10%, ash was 6.80%, fiber was 6.70%, energy was 289kcal, vitamin C was 5.10mg, vitamin A was 3.50mg, beta carotene was 32.00 µg, sodium was 10.60mg, magnesium was 9.00mg, potassium was 419mg, phosphorous was 15mg, calcium was 61mg and iron was 2.70mg.
- ✓ **Sweet potato - dates fruit bar**- SPD1 has 11.45% spread ratio, 11.23% total soluble solids, 63.02*14.66*35.21 of L*a*b which indicates colour, 0.958% of acidity, pH of 2.7, 44.06mg/g of reducing sugar. Hardness of SPD1 was 14.62 N and adhesiveness was 0.01062 Mpa. Moisture of SPD1 was 5.40%, ash was 4.46%, fiber was 5.69%, energy was 325kcal, vitamin C was 3.20mg, vitamin A was 2.90mg, beta carotene was 19.80 µg, sodium was 6.41mg, magnesium was

8.00mg, potassium was 489mg, phosphorous was 12mg, calcium was 55mg and iron was 5.20mg.

- ✓ **Sweet potato - guava fruit bar**-SPG1 has 12.25% spread ratio, 7.80% total soluble solids, 56.02*12.98* 32.54 of L*a*b which indicates colour, 0.704% of acidity, pH of 3.8, 42.36mg/g of reducing sugar. Hardness of SPG1 was 9.10 N and adhesiveness was 0.01024 Mpa. Moisture of SPG1 was 11.00%, ash was 5.43%, fiber was 5.90%, energy was 264kcal, vitamin C was 15.60mg, vitamin A was 4.20mg, beta carotene was 12.10 µg, sodium was 9.25mg, magnesium was 19.00mg, potassium was 522mg, phosphorous was 32mg, calcium was 25mg and iron was 1.10mg.
- ✓ **Sweet potato - nendran banana fruit bar**- SPB1 has 10.70% spread ratio, 10.08% total soluble solids, 59.03*14.88*36.02 of L*a*b which indicates colour, 0.583% of acidity, pH of 6.3, 56.09mg/g of reducing sugar. Hardness of SPB1 was 11.75 N and adhesiveness was 0.01093 Mpa. Moisture of SPB1 was 12.10%, ash was 6.28%, fiber was 5.20%, energy was 314kcal, vitamin C was 10.09mg, vitamin A was 3.26mg, beta carotene was 9.32 µg, sodium was 13.40mg, magnesium was 11.26mg, potassium was 581mg, phosphorous was 23mg, calcium was 49.50mg and iron was 1.67mg.

According to the findings of this study, variant I scored the highest for all fruit bars (SPA, SPD, SPG and SPB). Physiochemical properties show that SPA1 has a higher spread ratio (12.88%), SPD1 has the greatest TSS (11.23%), and SPD1 has a higher acidity value (0.958%) than SPA1, SPG1, and SPB1. The pH of SPB1 is higher (6.3) than another three fruit bars. Colour value L, a, b SPA1 (54.05*16.62*45.69), SPD1 (63.02*14.66*35.21), SPG1 (56.02*12.98*32.54), and SPB1 (59.03*14.88*36.02) indicate that all four fruit bars were more oriented toward black with red and yellow. When compared to SPA1, SPG1, and SPD1, SPB1 has a higher reducing sugar (56.09mg/g).The texture results show that SPD1 has a higher hardness (14.6234N) than the other three fruit bars, and SPB1 has a higher adhesiveness (0.01093Mpa) than SPA1, SPD1, and SPG1. The nutrient composition of fruit bars demonstrates that SPA1 has a greater moisture content (12.10 percent), ash (6.80g), and fiber (6.70g) content than SPD1, SPG1, and SPB1.

Among the four fruit bars, SPD1 has the highest energy value (325kcal). When compared to the other three fruit bars, SPG1 has the highest vitamin A (15.60 mg) and vitamin C (4.20 mg) content. SPD1, SPG1, and SPB1 all contribute less beta carotene than SPA1 (32.00µg). SPB1 has a high sodium level (13.40 mg) and a high magnesium content (19.00 mg).SPB1 has a lot of potassium (581mg). SPG1 had the greatest phosphorus score (32 mg) and the highest calcium score (61 mg). SPD1 has a higher iron concentration (5.20mg) than SPA1, SPG1, and SPB1.

SPD1 is rich in iron and highly recommended for adolescent girls as it may reduce the risk of anaemia. SPB1 serves as a good energy source before workout. Vitamin A and C is rich in SPG1 and helps to improve vision and develop immunity. SPA1 is high in fiber and beta carotene, so it reduces constipation and improve the vitamin A level. These fruit bars serve as a excellent snack for people of all age goups. It reduces sweet cravings. It is the easiest way to incorporate fruits in daily meal as children mostly refuse to take it and it is a best replacement for chocolates.

The study was presented in the Institutional Human Ethics Committee, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore and the approval was obtained. The human ethical clearance approval number is AUW/ IHEC/ FSN -20-21/XPD-22 and is appended in Appendix I.

Recommendations for further research:

- Development of fruit bar with other fruits like tomato, papaya, gooseberry and pear in combination with sweet potato.
- Identification of phytochemicals present in the fruit bar
- Fortification of fruit bar with vitamins and minerals
- Clinical trials on fruit bar on people with vitamin A and vitamin C deficiency
- Commercialisation of fruit bar in markets and online.

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APPENDICES

VII. APPENDIX I

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

08th March 2022

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

Dear ShobanaK,

Ref: Your proposal No. IHEC/21-22/FSN-22 entitled "Development of Fruit Bar Rich in Beta Carotene and Vitamin C" resubmitted for approval to IHEC on 02.03.2021.

The Institutional Human Ethics Committee of our University hereby grants approval to your research proposal No. IHEC/21-22/FSN-22 entitled "Development of Fruit Bar Rich in Beta Carotene and Vitamin C" resubmitted by you. The Approval number for the same is AUW/IHEC/FSN-21-22/XPD-22.

We wish you all the best in your research endeavours.

Regards,

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

Institutional Human Ethics Committee

APPENDIX II

SCORE CARD FOR SENSORY EVALUATION

Name :

Class :

Date :

Sweet potato – apple fruit bar (SPA)

Code	Appearance	Colour	Flavour	Texture /mouthfeel	Taste	Overall Acceptabililty
Standard						
SPA1						
SPA2						
SPA3						

Sweet potato – dates fruit bar (SPD)

Code	Appearance	Colour	Flavour	Texture /mouthfeel	Taste	Overall Acceptabililty
Standard						
SPD1						
SPD2						
SPD3						

Sweet potato – guava fruit bar (SPG)

Code	Appearance	Colour	Flavour	Texture /mouthfeel	Taste	Overall Acceptabililty
Standard						
SPG1						
SPG2						
SPG3						

Sweet potato – nendran fruit bar (SPB)

Code	Appearance	Colour	Flavour	Texture /mouthfeel	Taste	Overall Acceptabililty
Standard						
SPB1						
SPB2						
SPB3						

Hedonic Rating Scores:

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

Signature