EXTRUDED SNACKS WITH BYPRODUCTS OF COCONUT

A dissertation submitted by

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For the partial fulfillment of the degree of

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In

FOOD PROCESSING TECHNOLOGY

Under the guidance of

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DECLARATION

I, ANJANA SALI, hereby declare that the dissertation entitled "EXTRUDED SNACKS WITH BYPRODUCT OF COCONUT" submitted to MAHATMA GANDHI UNIVERSITY in partial fulfilment of the requirements for the award of the degree of Master of Vocational Studies in Food Processing Technology is a record of original research done by me under the supervision and guidance of Dr Chetana R, Principal Technical Officer ,Department of Traditional Foods And Applied Nutrition, CSIR-CENTRAL FOOD TECHNOLOGICAL RESEARCH INSTITUTE , Mysuru. I further declare that; the results of the present study have not formed the basis for the award of any other degree to any present candidate of any university during the period of my study.

Place: Mysuru **ANJANA SALI**

Date:

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ANJANA SALI

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ABREVATION

CTC	COCONUT TESTA PHENOLIC CONCENTRATE
CTF	COCONUT TESTA FIBER
CF	COCONUT FIBER
SR	SAMPLE RESIDUE
SPR	SAMPLE PROTIEN RESIDUE
SAR	SAMPLE ASH RESIDUE
CB	CORRECTED BLANK
GAE	GALLIC ACID EQUIVALENTS
TPC	TOTAL PHENOLIC CONTENT
DPPH	2,2-DIPHENYL-1-PICRYLHYDRAZYL
Ao	ABSORBANCE OF THE CONTROL
A1	ABSORBANCE OF THE SAMPLE

ABSTRACT

The objective of the current study was to develop and formulate an extruded snack product utlizing by-product of coconut. The outer brown layer of copra, known as coconut testa, dry testa and wet testa are obtained as by-products of coconut processing. Wet coconut testa oil and defatted wet testa extract contain higher levels of tocopherols, tocotrienols, phenolics, phenolic acids, and flavonoids compared to dry coconut testa oil or defatted dry testa extracts. A snack was prepared using these ingredients along with barnyard millet, corn grits, coconut fibre, coconut testa fibre and coconut testa concentrate by extrusion technology to obtain a polyphenol rich extruded snack.

Extruded snacks were formulated in four variations with control and added coconut fibre(CF), coconut testa fibre(CTF), and coconut testa concentrate(CTC). The developed extruded snacks were analysed for their physico chemical analysis such as moisture, ash, protein, fat, carbohydrate, bulk density, tap density, radical scavenging activity by DPPH and total phenolic content (TPC). The colour, texture and sensory analysis were analysed for the confirmation of the functional properties of formulated extruded snack.The result of the study showed that moisture content ranged from 0.76 to 1.27%, ash value ranged between 2.99 to 3.19%, protein value ranged from 9.85 to 10.49%, and more fibre content is showed by CF. The radical scavenging activity IC50 value of 0.46 and coconut fibre IC50 value of (CF) 0.90 and TPC ranged between, 0.07 to 0.76 GAE (mg) per gram.The product with added testa phenolic showed the more bioavailability of phenols which is very much health beneficial.

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INTRODUCTION

Food extrusion is the technique of forcing low-moisture food components through a specifically made die to mix, homogenize, and shape them into intermediate or completed products. The Latin words "ex" (out) and "trudere" (to shove) are the roots of the English word "extrudate." (Tadmor&Klein1970). Extrusion consists in forming and shaping a dough-like material by forcing it through a restriction called the die. The extrusion method is widely utilized in the cereal-processing sector to transform cereal flours through kneading, cooking, shaping, and texturizing. The outcome is an array of ready-to-eat food items like noodles, pastas, breakfast cereals, baby foods, and snacks (Bouvier&Campanella,2014).

This category of food has the greatest potential for growth among the snack foods. The snacks can be produced using innovative methods that capture the consumer imagination. Snack products are being made from a variety of ingredients. However, the selection of the ingredients are limited by the equipment availability. The introduction of the extrusion process, other processing equipment's, and better knowledge of extrusion technology have led to more diverse and complex formulations for snack foods. The most common sources of ingredients are corn, wheat, rice, potato, tapioca, and oats. There are several other sources of ingredients for snack food all over the world. A major ingredient in snack food formulation is starch. In its natural form, the starch is insoluble, tasteless, and unsuited for human use. To make it digestible and acceptable, it must be cooked.

Extruded snacks can be categorized into various types, but for the purpose of this review, second and third generation snacks will be focused. Second generation snacks, also known as directly expanded snacks or collets, constitute the majority of extruded snacks, such as puffed snacks. These snacks have the flexibility to undergo seasoning, baking, or frying processes. In contrast, third generation snacks, also referred to as indirectly expanded snacks or half products, are combined during the extrusion process, dried into pellet form for shelf stability, and subsequently expanded through frying, hot air, or microwaving at a later stage. (VanderSman&Broeze,2014).

In India, coconut is mainly consumed in the form of fresh nuts, tender coconuts, and coconut oil. Value addition in coconut is only to the tune of 8% of the production. Coconut offers a diverse range of consumable products, including oil, kernel, tender nut water, toddy, neera, coconut sugar, immature inflorescence, and haustorium. Despite concerns that coconut oil may elevate blood cholesterol levels and thus pose a risk of heart disease, there is substantial research indicating its health benefits due to its unique fatty acid composition. The wet processing of fresh coconut kernel results in virgin coconut oil (VCO), which is highly nutritious and possesses significant health-promoting properties. Coconut oil has antibacterial, anti-protozoan and antiviral properties because of the medium chain fatty acids. Apart from coconut oil, coconut kernel contains many beneficial factor (RajamohanandArchana2018). The coconut testa, or mesocarp, is the brown covering of the coconut endosperm, and it holds significance in coconut processing industries. It is typically discarded after coconut paring during the preparation of various products like coconut milk, desiccated coconut, and virgin coconut oil (VCO). Its presence during the production of VCO and other items like desiccated coconut results in an undesirable brown coloration in the final products. Consequently, the coconut testa is often disregarded and disposed of without being explored for potential product development scopes.

A study was carried out to utilize testa as a source of edible oil. The antioxidant richness of coconut testa oils because of their rich phenolics, tocotrienols and tocopherols constituents. The abundant presence of phenolics, tocotrienols, and tocopherols in coconut testa oils contributes to their high antioxidant content. This antioxidant capacity, along with the ability of coconut testa oil extract to shield human serum albumin from oxidative damage induced by hydrogen peroxide, highlights its potential as a valuable ingredient in functional foods (Zhang etal.2016).

Wet coconut testa oil and defatted wet testa extract contain higher levels of tocopherols, tocotrienols, phenolics, phenolic acids, and flavonoids compared to dry coconut/copra testa oil or defatted dry testa extracts. Since testa oils contain greater quantities of unsaturated fatty acids and beneficial compounds compared to standard coconut oil and consequently promote the health advantages to consumers. The defatted testa along with its extract, could be utilized in the preparation of nutritious foods, particularly suitable for diabetic and obese individuals. Further research into testa oil and defatted testa extracts is warranted, particularly concerning their antioxidant, antiviral, and antidiabetic properties in humans. Hence testa oil, defatted testa, and its extract exhibit promising potential for enhancing health.(Prakruthi et al 2021).

In our study these bioactive rich raw materials or by-products of coconut, industry was utilized to prepare an extruded ready to eat product rich in healthy polyphenols.

OBJECTIVES

1. Development and formulation of extruded snacks with by-product of coconut.
2. Polyphenol rich extruded snacks were developed.
3. Physico chemical analysis of developed extruded snack.
4. Sensory attributes of extruded snacks

REVIEW OF LITERATURE

3.1 COCONUT

The coconut, scientifically known as *Cocos nucifera*., holds significant global importance as a fruit tree, serving as a vital source of sustenance for millions of individuals, particularly in tropical and subtropical areas. Renowned for its multifaceted utility, it is frequently referred to as the “tree of life”. Globally, Coconut (*Cocos nucifera* L.) is widely recognized as one of the most significant and extensively cultivated palm trees with each part of the plant serving several essential purposes (Bourdeixetal.,2006). The dried fruit (endosperm) is used to make coconut oil, which is refined using alkali treatment, bleaching, and deodorization; while virgin coconut oil is made without using any of these chemicals. It is well known to have numerous health advantages (Krishnaetal2010). Coconut harvested from coconut palms and widely consumed, especially in regions like Southeast Asia and the Caribbean, undergoes compositional changes influenced by factors such as age and variety. Each month, a new cluster of coconuts develops, replacing the previous one. Throughout the year, both the weight of the coconut kernel and the volume composition of coconut water undergo considerable alterations as the coconuts mature and increase in size (Mat et al., 2022). Coconut by-products and products themselves have a variety of commercial uses. Coconut is both an oil seed crop and a food source. It provides fuel, fiber, and lumber as well. In various states around the nation, coconut palms are grown for their drinks. The West Coast Indian population consumes kernels as a staple in their diet. The kernel gives nutritious milk when boiled, and it also produces oil. Coconut milk is essential in many culinary dishes (Muralidharan, & Jayashree 2011). Approximately 35% of the production is processed into copra, while 11% is allocated for tender nuts. Just 2% is dedicated to seed purposes, with a similarly small percentage utilized for value addition and industrial applications (Muralidharanetal.,2011).

For millions, coconuts play an important role in providing sustenance, employment, and entrepreneurial prospects. It is recognized as a "wonder fruit" due to its abundant macro and micronutrients which are essential for human health. Coconuts are extensively utilized in various commercially processed forms. These include desiccated coconut, oil, raw kernels, milk, and coconut water (Matetal.,2022). The versatility of coconut sets it apart, boasting hundreds of uses unmatched by any other oilseed or horticultural crop. Serving as both a food source and an oilseed crop, coconut additionally provides valuable resources such as fiber, timber, and fuel (Muralidharan et al., 2011). Scientists have extensively studied these properties, revealing a range of health benefits including antibacterial, antihypertensive, oral microflora inhibitory, antiviral, antifungal, antidermatophytic, antiparasitic, hypoglycemic, immunostimulant, and hepatoprotective effects (Gardens.,2014; Airaodionetal.,2019; Joshua etal.,2019)

Coconut proteins, oil, and water play major roles, along with derived products such as coconut palm sugar, inflorescence, haustorium, and various nutraceuticals. These are essential for preventing nutrient deficiencies and promoting health benefits as a dietary supplement. It is used as cooking oil, with significant medicinal values. It is also used as an effective cosmetic and therapeutic skincare ingredient. At present, coconut is highly valued as a holistic source of nutrients, aiding in addressing malnutrition and combating illness (Perera.,2014).

Coconut is believed to have its origins in the Indo-Malayan region, from where it spread throughout the tropics. Although it is now found on soils ranging from pure sand to clays and from mildly acidic to alkaline, its native habitat was the narrow sandy shoreline. It is non-invasive, and most of its spread has been caused by humans, especially when it has moved farther inland from its natural habitat. It does best in warm, humid environments, while it may survive brief temperatures below 21°C (70°F). It is easily recognized by its clusters of big fruits held atop long, slender stems and its crown of feather-like fronds (EdwardandElevitch2006). Protein that is both hydrophobic and hydrophilic can be found in abundance in defatted coconut flour. Proteins have the potential to interact with water because of their hydrophilic portion. Furthermore, there is a lot of soluble fiber in coconut flour, which may improve water absorption.

Coconut oil and fatty acids give it antiviral, antibacterial, and antiprotozoal qualities (Bhatnagar etal2009). Natural antioxidants such as phytosterols, tocopherols, tocotrienols, and phenolics are found in trace amounts in coconut oil. Foods high in polyphenols have been shown to have anti-oxidant, free radical-scavenger, and peroxidation-inhibiting properties (Wu et al., 2006). Additionally, it lowers cardiovascular illnesses and has anti-carcinogenic properties (Bravo 1998). Plants that produce oilseeds are the main sources of phytosterols. Legumes, vegetables, and unprocessed vegetable oils contain them in addition to nuts (Weihrauch & Gardner 1978). Fat-soluble antioxidants with vitamin E activity are called tocopherols. Coconut oil, palm oil, and oil derived from bran sources including wheat and rice bran all contain tocotrienols. Tocotrienols are absent from other vegetable oils in meaningful concentrations. They function to prevent polyunsaturated fatty acids' membrane lipid peroxidation (Wagneretal.,2001).

The following description applies to the tall variety of coconuts, which is the dominant type grown the world over.

- Scientific name: *Cocos nucifera L.*
- Family: *Arecaceae* (palm family)
- Subfamily: *Cocoideae*
- Non-preferred scientific names: Palma cocos Miller (EdwardandElevitch2006)

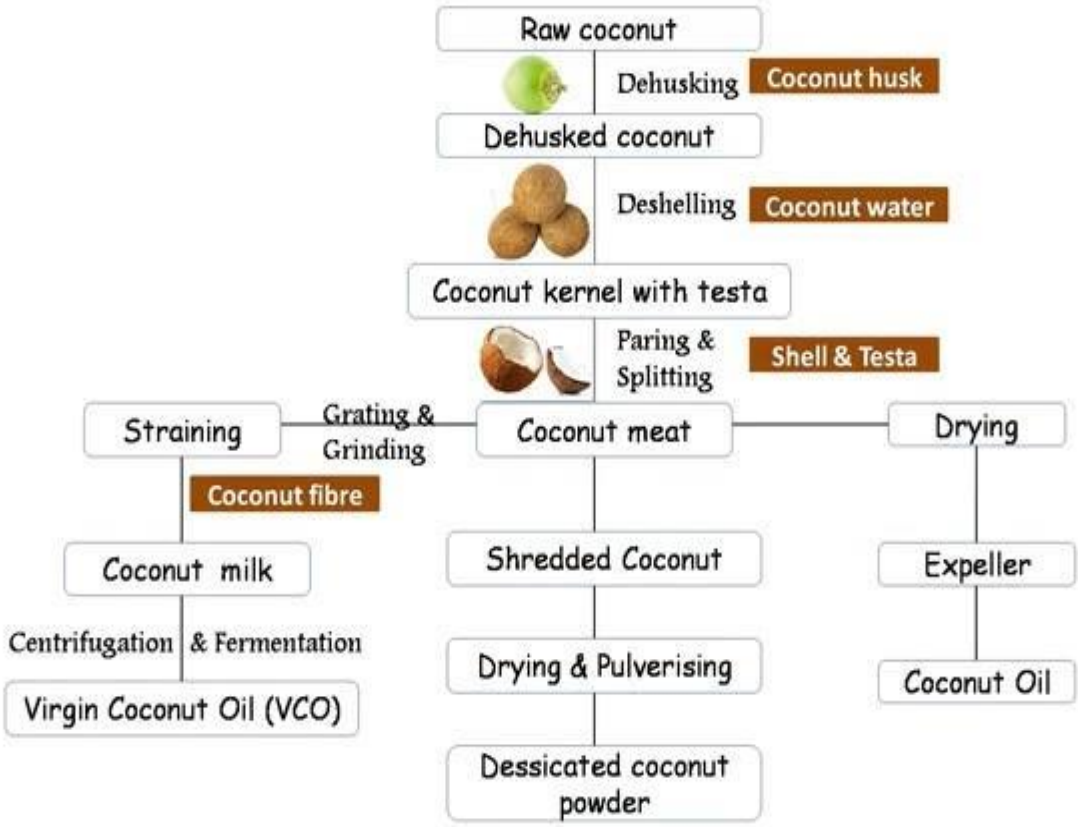


Figure 3.1 Flowchart of coconut processing

3.2 COCONUT TESTA

The outer layer of the coconut kernel, known as the testa, which is brown in color and acts as a protective cover. However, this characteristic do contributes an undesirable dark color to coconut-derived products like desiccated coconut powder, coconut cream, and milk powder (ShunmugiahVeluchamyetal.,2023). It is acquired as a by-product from coconut processing industries. It is attained during the production of items such as desiccated coconut, coconut milk, and virgin coconut oil.

Coconut testa is the thin and dark outer layer of the coconut kernel. The coconut testa, also known as the coconut husk or coir, refers to the fibrous outer layer that surrounds the hard coconut shell. It is located between the hard shell and the coconut meat. The coconut testa, or coconut husk, is primarily composed of fibrous material which protect the inner kernel of the coconut and does not have significant nutritional value for human consumption. It is not typically consumed directly as a food source. However, the inner portion of the coconut, the coconut meat or flesh, is highly nutritious and is commonly consumed.

While the consumption of coconut kernel offers various health benefits to humans, the coconut testa often goes unused and is wasted (Appaiahetal.,2014). Within the coconut industry, the testa, or outer covering, holds particular significance as a valuable by-product. Traditionally, the process of removing the testa occurs subsequent to coconut deshelling and is typically carried out manually (Marikkar and Madurapperuma, 2012). Despite containing valuable secondary metabolites such as polyphenolic compounds, tocopherols, and tocotrienols, which have the potential to offer health advantages to humans, the coconut testa is underutilized (Oliveiraetal.,2011).

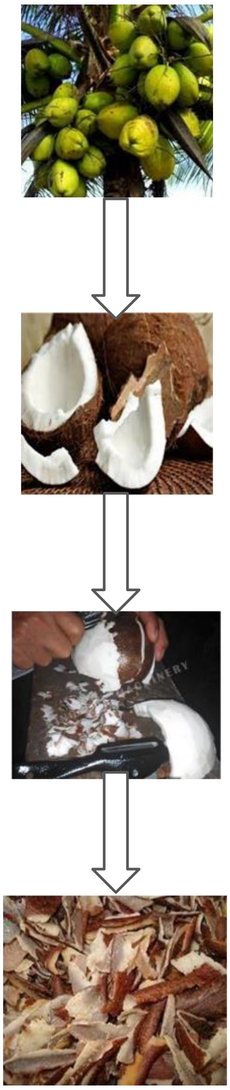


Figure 3.2 Method of Testa Processing

Coconut testa is rich in fat and it is about 34.7% on a wet weight basis. Testa contains fiber and oil that has a bitter taste due to the presence of polyphenols. This testa is also used as animal feed. The polyphenols have antioxidant properties and the natural antioxidant concentrate prepared from coconut testa can be incorporated as an ingredient in a variety of food items (Appaiah et al., 2014). These compounds range from simple phenolic acids to complex polyphenols like flavonoids, tannins, and anthocyanins. These phytochemicals are derived from plants and are recognized for their antioxidant and anti-aging properties, as well as their potential to improve physical health and combat degenerative conditions such as cancer, diabetes, hypertension, and cardiovascular issues (PandeyandRizvi.,2009; Manachetal., 2004; Everitt et al., 2006; Dzialo et al., 2016). Despite its richness in polyphenols, the utilization of testa is primarily limited to being serving as a raw material for biodiesel production (Swaroopetal.,2016), or often discarded outright, overlooking its potential as a valuable source of polyphenolic compounds.

The chemical composition analysis of coconut testa revealed major constituents such as 16 phenolic acids and 12 flavonoids, which provide additional evidence of its innate antioxidant abilities (Arivalaganetal.2018b).

3.3 COCONUT TESTA OIL

Coconut testa oil obtained from copra testa and wet coconut testa contains 313.9 µg% and 389.0 µg% of polyphenolics, respectively, while the levels of tocopherols are measured about 22.3 mg% and 100.1 mg%, respectively. A comparative analysis of the phytochemical composition of testa oils derived from wet coconut and copra, alongside oils extracted from whole coconuts, wet and copra kernels. The study revealed that coconut testa oils are notably rich in antioxidants, particularly tocopherols, tocotrienols, and phenolics, offering potential health advantages. Additionally, the phytochemical profile and antioxidant activity of testa extracts indicated the presence of carbohydrates, amino acids, glycosides, triterpenes, tannins, flavonoids, phenolics, and saponins as principal constituents. Moreover, the extract from wet coconut testa displayed notably high levels of phenolics and antioxidant potential. (Appaiahet al.,2014).

The antioxidant capacity and defensive properties of coconut testa oil extract against hydrogen peroxide-induced oxidative harm on human serum albumin highlight its potential as a functional food source. Thus, the standardized extraction protocols for coconut testa oil and demonstrated its ability to protect human serum albumin from oxidative damage induced by hydrogen peroxide, indicating promising therapeutic advantages (Zhang et al. 2016). The identification of various phenolic acids in coconut testa oils highlights the unexplored nutritional potential of this crop. It underscores the genetic variations in the biochemical properties of coconut testa oils (ShunmugiahVeluchamyetal.,2023).

3.4 CORN GRITS

Figure 3.3 Corm grits

In many regions, corn is a major source of nutrition and a staple crop. The main component of maize is starch, which is followed by fat, fiber, protein, and micronutrients including vitamins and minerals. Zein is the main storage protein, although zein is lacking in both basic and acidic amino acids, particularly tryptophan and lysine. Corn contains non-nutrient phytochemicals such as phenolic acids, anthocyanins, and carotenoids in addition to macronutrients and micronutrients. Carotenoids, anthocyanins, and phenolic acids have demonstrated numerous health advantages related to reducing the risk of chronic illnesses, including their ability to prevent obesity and have anti-inflammatory, anti-hypertensive, and anti-cancer properties. (jingwenXuetal2019).

In the food processing sector, corn extrudates made with different kinds of flour are often utilized for both finished products and flour modification (AntunJozinovićetal2016). A wide range of snackable foods and morning cereals are produced by extrusion technology. Cereal grains are a common source of raw materials for food extrusion because of their high starch content. Corn grit (CG), which is produced by dry milling maize, is the primary ingredient in the majority of commercially available extruded goods. All the properties that are desired for producing highly acceptable extruded goods are more offered by corn grits. On the other hand, because maize extrudates contain less number of vital elements, including minerals, dietary fiber, essential amino acids, and proteins(Khetan ShevkanI et al 2019).

3.5 BARNYARD MILLET

Figure 3.4 Barnyard millet

Barnyard (*Echinochloa frumentacea*) is a fast-growing millet crop that matures within 90-100 days. They provide essential nutrients such as niacin, magnesium, phosphorus, manganese, iron, and potassium. They are high in protein, fiber, vital amino acid like methionine, lecithin, and vitamin E. Barnyard millet has the ability to be harvested numerous times per year, and high in micronutrients, and phytochemical contents were presented. While consuming barnyard millet there are several health benefits, including protection against diabetes, cardiovascular disease, obesity, skin disorders, cancer, and celiac disease. Barnyard millet flour is gluten-free and suitable for celiac and diabetes diets. While considering the nutritional value of millet, various food products like bread, snacks, baby foods, millet wine, porridge, fast foods, and millet nutrition powder can be prepared. Further research and development of barnyard millet and its products may aid in the treatment of a variety of human ailments.

3.6 EXTRUSION

Extrusion is a commonly used processing technology in the food industry with a wide number of applications. It's a processing mechanism that pushes food ingredients through a tiny aperture using one or more screws. Foods are cooked in the high-pressure, high-shear, and high-temperature environment produced by the screws inside the barrel as they are being driven through the extruder. Materials frequently puff as they escape because of the pressure release and steam generation from the water. The entire procedure can be completed in less than a minute and is continuous. Single-screw and twin-screw extruders are the most often utilized in the food sector; twin-screw systems are more popular due to their flexibility (Kowalskietal., 2017). Materials can have their characteristics changed through the application of extrusion technology. Specifically, the ability to integrate mechanical, thermal, and chemical activities in a single step and continuous mode makes twin-screw extrusion highly appealing. It is extensively utilized in the manufacturing of meals that have been altered, including cereals. Extrusion is another method that can be utilized to separate plant material, though. Pressing can be used to accomplish the transformation and express liquid extracts, such as vegetable oils. Before a post-treatment, twin-screw extrusion can also be utilized for the pre-treatment of raw materials, such as grinding. Additionally, extrusion makes it possible to extract compounds from fresh plants, including proteins (Vandenbosscheeta.,2019).

As a multi-step, multi-purpose, thermal/mechanical technique, extrusion cooking has made a wide range of food applications. There is uncertainty about how extrusion cooking affects nutritional quality. The breakdown of antinutritional components, the gelatinization of starch, the rise in soluble dietary fiber, and the decrease in lipid oxidation are among the positive consequences. However, depending on the types of raw materials used, their makeup, and the conditions of the process, Maillard reactions between sugars and proteins can lower the nutritional value of the protein. Heat-labile vitamins may be lost in different amounts. Alterations in the composition of proteins and amino acids, carbohydrates, dietary fiber, vitamins, minerals, and certain non-nutritive helpful food components can have either positive or negative effects (Shivendraetal2007).

Extrusion cooking is a high-temperature, quick-cooking method that causes molecular transformation and chemical reactions by plasticizing and cooking moistened, expansive, starchy, or proteinaceous food materials in a tube using a combination of pressure, temperature, and mechanical shear (Havck&Huber,1989; Castellsetal.,2005). Compared to other heat processes, this technology offers some special advantages since it subjects the material to extreme mechanical shear. It has the ability to break covalent bonds in biopolymers, and the extreme structural disruption and mixing allow food ingredients to be texturized or have their functional qualities changed (Asp&Bjorck,1989; Carvalho&Mitchelle,2000).

An increasing variety of dry pet foods and fish foods, textured meat-like materials from defatted high-protein flours, nutritious pre-cooked food mixtures for infant feeding, confectionery products, salty and sweet snacks, co-extruded snacks, indirect expanded products, croutons for soups and salads, and more uses have been found for the processing method (Harper, 1989; Eastman et al., 2001). Depending on the material and equipment utilized, the extrusion process is primarily a thermo-mechanical processing activity that incorporates various unit activities, such as mixing, kneading, shearing, conveying, heating, cooling, shaping, partial drying, or puffing. Food materials are typically exposed to a mixture of high temperature, high pressure, and high shear during the extrusion processes. The functional characteristics of the extruded material may alter as a result of a range of reactions.

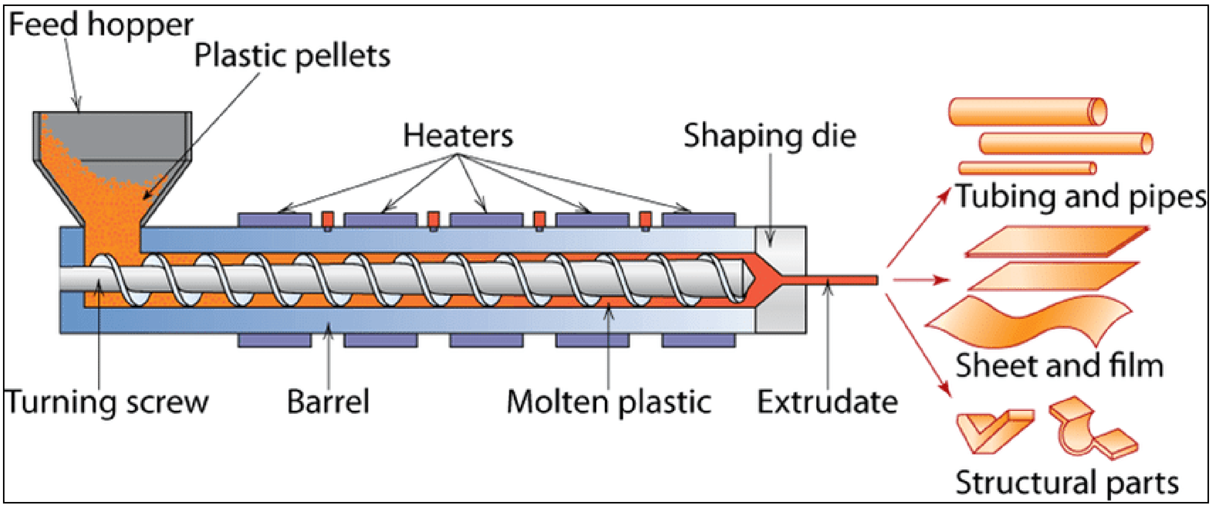


Figure 3.4 Food Extrusion Process

There are generally two main energy inputs to the system. First, there is the energy transferred from the rotation of the screws and secondly, the energy transferred from the heaters through the barrel walls. The main ingredients in extrusion are dry powdered materials, such as rice, wheat, and maize flour. The extruder's conditions change the dry powdered materials into fluids, therefore properties like particle cohesion, hardness, and surface friction become crucial.

Types of extrusion process:

Cold extrusion: The material which is to be extruded is below the recrystallization temperature.

Hot extrusion: The material which is to be extruded is above the recrystallization temperature.

When extrusion happens above the recrystallization temperature, which is roughly 50–60% of its melting point, it is referred to as hot extrusion. When the metal reaches the recrystallization temperature, hot extrusion requires less force than extrusion at a lower temperature. It is always possible to have a low surface polish because of scale formation on the extruded portion, which calls for a lot of maintenance. Cold extrusion is a gentle method of mixing and shaping dough without heating or boiling the dough inside the extruder. It is mostly used to make pasta in food processing.

Advantages of extrusion:

- Low cost per part
- Flexibility of operation
- In hot extrusion, post-execution alterations are easy as the product will still be in a heated condition.
- Continuous operation
- High production volumes
- Many types of raw materials can be used
- Good mixing (Compounding)
- The surface finish obtained is good
- Good mechanical properties obtained in cold extrusion

Disadvantages of extrusion:

- Variations in the size of the product.
- Product limitations as only one type of cross-section can be obtained at a time.
- High initial cost setup.

METHODOLOGY

4.1 MATERIALS

Corn grits, barnyard millet, coconut testa phenolic concentrate (extracted in CFTRI and procured for experiment) coconut testa fibre and other material was procured from the local market.

Chemicals: Sodium carbonate Anhydrous, Gallic acid, Folin - Ciocalteu(FC) reagent, DPPH reagent, 95% ethanol, petroleum ether.

Raw materials - Corn grits, Barnyard millet, Coconut testa phenolic concentrate, Coconut testa fibre, Coconut fibre, salt, chilli powder, masala mix, water.

4.2 COMPOSITION OF EXTRUDED SNACK

Table 4.1: Standard Composition of Extruded snack

INGREDIENTS	CONTROL (%)	CTC (%)	CTF (%)	CF (%)
Corn Grits	25	22.5	22.5	22.5
Barnyard Millet	75	72.5	72.5	72.5
Coconut Testa Concentrate	-	5	-	-
Coconut Testa Fibre	-	-	5	-
Coconut Fibre	-	-	-	5

*CTC – coconut testa phenolic concentrate, CTF – coconut testa fiber, CF – coconut fiber

Corn grits and barnyard millet were the basic ingredients added in the control and all other three variants. Coconut by-products such as coconut testa phenolic concentrate (CTC), coconut testa fiber (CTF), and coconut fiber (CF) were incorporated separately in each product variation, where CTC extruded snack had 5% coconut testa concentrate, CTF had 5% coconut testa fiber and CF had 5% coconut fiber. 42 g of spice mix was added to all the products separately. Each sample was added with 120 ml water to maintain optimum moisture whereas, in the case of the CTC snack product, 70 ml of water was added as it contained 5% CTC which is high in moisture content in comparative to others to obtain optimum moisture conditions.

(a)

(b)

(c)

(d)

Figure 4.1: Extruded snacks (a) control; (b) coconut fibre (CF); (c) coconut testa fibre(CTF); (d) coconut testa phenolic concentrate (CTC)

4.3 PYSICO CHEMICAL PROPERTIES

4.3.1 Estimation of Moisture content

Figure 4.2 Moisture Analyser

The moisture content of extruded products was determined using moisture analyser. 2g of sample was placed in the moisture analyser at 70 ºC and the results were interpreted.

4.3.2 Determination of fat content

The crude fat was estimated by the Soxhlet method according to AOAC (2000). Empty round-bottom flasks were weighed in order to calculate the fat content of the samples. 20g of sample were weighed and taken in thimbles. The Soxhlet apparatus extractor housed the thimbles. The extractor was filled with petroleum ether (40°C–60°C), and the entire device was fixed. Fat extraction was continued for 8 hours. Thimbles were taken out of the extractor once the extraction was finished, and petroleum ether was then distilled out of the flask using rotavapor. The flasks were maintained in the oven at 100° C to eliminate any remaining petroleum ether after the solvent had been entirely removed. After cooling in a desiccator, the flasks were weighed. The percentage fat was calculated by the formula:

$$\text{Fat Content (\%)} = \frac{\text{Difference in the weight of the round bottom flask x 100}}{\text{Sample weight (g)}}$$

4.3.3 Determination of Ash content

Ash is the inorganic waste left over after samples are burned in a muffle furnace. It serves as an indicator of the mineral content of the samples. The ash content was measured using the AOAC (2000) technique. 5-10g of samples were weighed and placed into labelled, pre-weighed silica crucibles. It was burned over a hot plate until it was completely charred. After that, the crucibles were moved to a muffle furnace that was kept at 550–600°C until light grey ash formed or the weight remained constant. The weight was then recorded after the crucibles cooled in a desiccator. The percentage of ash content is determined by the formula:

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

4.3.4 Protein Analysis

Figure 4.3 Protein Analyser

Protein analyzer was used for the determination of Nitrogen concentration and the relative Protein content in organic and inorganic chemical products and substances of different natures and origin. Samples can be in solid, liquid, or gaseous form. The FLASH 2000 Series has revolutionized the process for accurately determining nitrogen levels. 30-60mg extruded samples weighed and were placed in Tin capsules, which were then automatically loaded into the sampler and introduced into an oxidation/reduction reactor heated to a temperature between 900 and 1000 °C. Precisely measured oxygen is injected into the reactor at the optimal moment for combustion. The reaction between oxygen and the Tin capsule at high temperatures triggers an exothermic process, briefly elevating the temperature to 1800 °C. This intense heat converts both organic and inorganic substances into elemental gases. Following further reduction, these gases are separated in a chromatographic column and detected by an extremely sensitive thermal conductivity detector.

4.3.5 Dietary fibre analysis

Dietary fibre in sample was analysed by AOAC (985.29) method. Weighed accurately 1g of defatted samples and mixed with phosphate buffer (0.08 M. pH- 6) in a beaker, magnetic stirrer bar was added. 100 µL of the heat-stable amylase solution should be added to this, well mixed, and covered with aluminium foil. The mixture was chilled by placing it in a water bath (95–100°C) for 30 minutes. After using 10 mL of distilled water to rinse the flask, add 100 µL of the protease solution, then use 10 mL (about) of sodium hydroxide (0.275 N) to adjust the pH to 7.5±0.2. The flask is then incubated at 60°C for 30 minutes in a water bath. After cooling, use 10 mL (about) of hydrochloric acid (0.325 N) to adjust the pH to 4.5±0.2 After adding 200 µL of the amyl glucosidase solution, the mixture was incubated for 30 minutes at 60°C. After removing the magnetic stirrer bar, 280 mL of 60°C preheated 95% ethanol was added, and the mixture was allowed to precipitate for 60 minutes. used a filtration device to filter the precipitate before transferring it to a celite crucible. The filtered residue was dried in a hot air oven at 105°C for an entire night after being rinsed with three 20 volumes of 78% ethanol, two 10 mL volumes of 95% ethanol, and two 10 mL volumes of acetone. Blank and duplicate runs occurred simultaneously. One duplicate residue was examined using the Kjeldahl method to determine the amount of undigested protein, and the other was burned for five hours at 550°C in a muffle to determine the amount of ash.

$$\text{Total Dietary fibre (\%)} = \frac{\text{Corrected sample residue} \times 100}{\text{Sample weight (g)}}$$

Corrected sample residue = SR-SPR-SAR-CB(g)

Where,
SR= Sample residue
SPR= Sample protein residue
SAR= Sample ash residue

CB= Corrected blank (average blank residue – blank protein residue – blank ash residue)

4.3.6 Carbohydrate

Total carbohydrate content of a food must be calculated by subtractions of the sums of the protein, total fat, moisture and ash. Along with fats and proteins, carbohydrates are one of the three major macronutrients included in food. Organic substances known as carbohydrates are composed of carbon, hydrogen and oxygen atoms, often in the ratios of 1:2:1. The main purpose of carbohydrates in the diet is to give the body a source of energy.

$$\text{Carbohydrate (\%)} = 100 - (\%\text{moisture} + \%\text{fat} + \%\text{protein} + \%\text{ash})$$

4.4 ANTIOXIDANT PROPERTIES

4.4.1 Total Phenolic Content

The total phenol content of the extrudates was determined colorimetrically at 760nm using the Folin-Ciocalteau reagent. 80% of ethanolic extraction is done for each extrudate. 100µl extract, 900µl distilled water, and 1ml of 1:1 Folin–Ciocalteau reagent were taken in test tubes. After 3 minutes, a saturated solution of Na2CO3 was added. The volume was made up to 3ml using distilled water. The dilution factor of CTC, CTF, CF were 200, 30 and 10 respectively. Gallic acid was used as a standard. After 30 minutes of incubation at room temperature, the absorbance of the samples was measured at 760 nm against a blank using a single-beam ultraviolet–visible spectrophotometer. A standard curve of Gallic acid was graphed and used to measure the TPC of samples, expressed as milli gram Gallic acid equivalents (GAE) per gram of sample.

4.4.2 Determination of Radical Scavenging Activity(DPPH)

Radical scavenging activity assay using DPPH (2,2-diphenyl-1-picrylhydrazyl) is a widely used method in antioxidant studies to evaluate the ability of compounds or samples to neutralize free radicals. A synthetic stable free radical called DPPH is visible as a purple solution. The stable free radical is scavenged by the antioxidants in the compound which is seen as a reduction in colour intensity. Gallic acid, a naturally occurring polyphenol was used as a standard since it exhibits a strong antioxidant and radical scavenging ability.

For radical scavenging assay, each sample of extruded products was extracted. 100µg/ml of Gallic acid solution and 0.1mM DPPH solution was prepared. 100µl of extract and 3ml of

DPPH solution were mixed in test tubes, where the blank was without sample. The dilution factor of CTC, CTF, and CF were 200, 60 and 10 respectively. The volume was made up to 3ml, using ethanol. After 30 minutes of incubation at dark environment, the absorbance was measured at 517nm against a blank in using a single-beam ultraviolet–visible spectrophotometer. The radical scavenging capacity was calculated by using the following equation, the representation of the result is done in the IC50 values.

$$\text{Radical scavenging activity (\%)} = \frac{(A_0 - A_1) \times 100}{A_0}$$

A_0 = The absorbance of the control.

A_1 = The absorbance of the sample.

4.5 FUNCTIONAL PROPERTIES

4.5.1 Bulk density

Bulk density is the mass of a substance per unit volume, which includes the volume filled by the voids or empty spaces between its particles. It gauges how firmly the material particles are packed into a certain specific volume.

In duplicates, take 10g of the finely powdered sample. A 100ml dry measuring cylinder was filled with 50ml water. Record the value in millilitres (ml) by gently tapping it on the counter using a rubber mat or cloth. Write the sample's bulk density as g per 100 millilitres.

$$\rho \text{ (g/ml)} = m / V$$

Where, ρ- Density (g/cm^3), m- Mass (g), V- Volume (ml)

4.5.2 Tap density

The density attained after tapping or mechanical compression is referred to as the tap density of a product. Usually, it is expressed in grams per milliliter (g/ml). The tap density of a material describes how tightly its particles can be compressed. It is a measurement of the maximum bulk density that the substance can reach under tapping forces. To calculate tap density of substance, a measuring cylinder with a known volume was filled with a known amount of flour and tapped 25 times. The volume occupied by the flour was then noted.

$$\rho \text{ (g/ml)} = m / V$$

Where, ρ- Density (g/ml), m- Mass (g), V- Volume (ml)

4.6 Colour Analysis

Figure 4.4 Colorimeter

The Minolta spectrophotometer operates on the spectrophotometry principle, which involves measuring the absorption and reflection of light by a sample at various wavelengths. The CM-5 is a very versatile bench-top spectrophotometer to measure the colour of solid, pasty, and liquid samples either in reflectance or transmittance. The circumstances of the extrusion process and the composition of the feed materials have a significant impact on colour analysis. Colour changes that occur during the extrusion process reveal the degree of cooking and pigment degradation. Extruded snack was measured in a Minolta Colorimeter CM-5 (Konica Wot Business Technologies, Hannover, Germany) where L* represents the lightness of the sample (0 is black and 1 is white), a and b are colour wherein +a is red, -a is green, +b is yellow and -b is blue. Triplicate readings of each sample were taken, and computerized data were obtained. The Beer-Lambert law, which states that the amount of light absorbed by a sample is proportional to the concentration of the absorbing species in the sample, forms the basis for the operation of this system. The total colour difference was calculated by applying the equation.

4.7 Texture Profile Analysis (TPA)

Figure 4.5 Texture Analyser

TPA was performed using a texture analyzer (Model CT3, Brookfield Engineering Laboratories, USA) using the double compression method. It was compressed to 50% shear using a 35mm cylindrical probe at a speed of 0.5 mm/s to carry out the TPA analysis. Hardness, adhesive force, springiness, gumminess, and cohesiveness were determined, and the values reported were the means of ten replications.

4.8 Sensory Analysis

The sensory evaluation of the finalized extruded snack was assessed using 15-point hedonic rating scale. It was organized in a calm environment and ventilated room while upholding standards. The evaluation indicates consumer preference and acceptance of the final product. For each panel member, a separate scorecard will be provided.

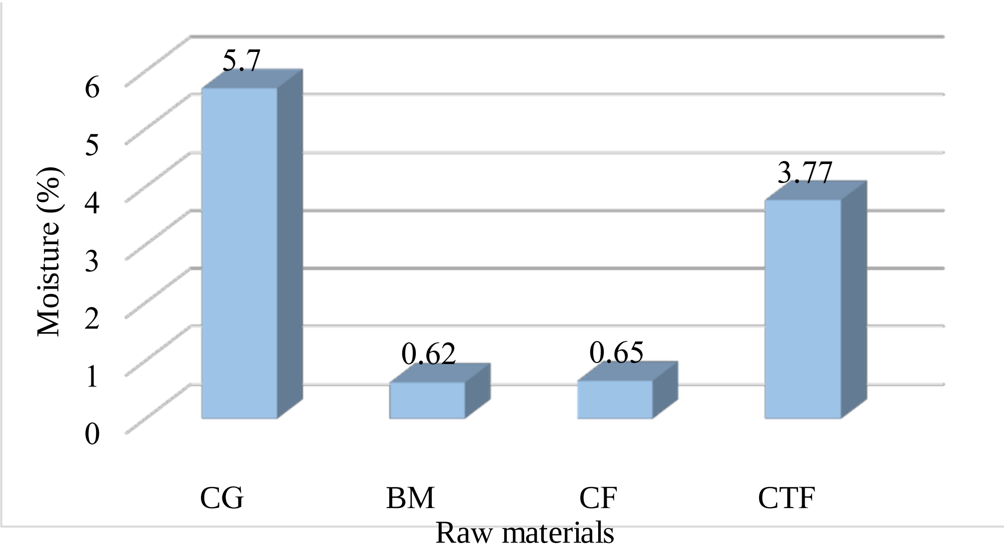
Sensory evaluation was carried out on extruded snacks made up of corn grits, barnyard millet, and the by-products of coconut at optimized extrusion conditions. Sensory approaches are quick, and easy, and deliver high-quality data. The senses of sight, touch, and smell are all included in the sensory analysis. A semi-trained panel of 12 members was selected for the test. The panel members were asked to mark the product's colour, taste, texture, mouthfeel, off-taste, and overall acceptability according to the15-point scale.

RESULT AND DISCUSSION

Extruded snacks were formulated using corn grits and barnyard millet along with the addition of coconut byproducts. Four variations of extruded snacks were formulated and standardized. Control was prepared using corn grits and barnyard millet. Coconut by-products such as coconut testa phenolic concentrate (CTC), coconut testa fibre (CTF), coconut fibre (CF) was incorporated separately into the products. The results of various analyses carried out for these raw materials and extruded snacks are discussed below.

5.1 Physico chemical analysis of raw materials

5.1.1 Moisture Analysis

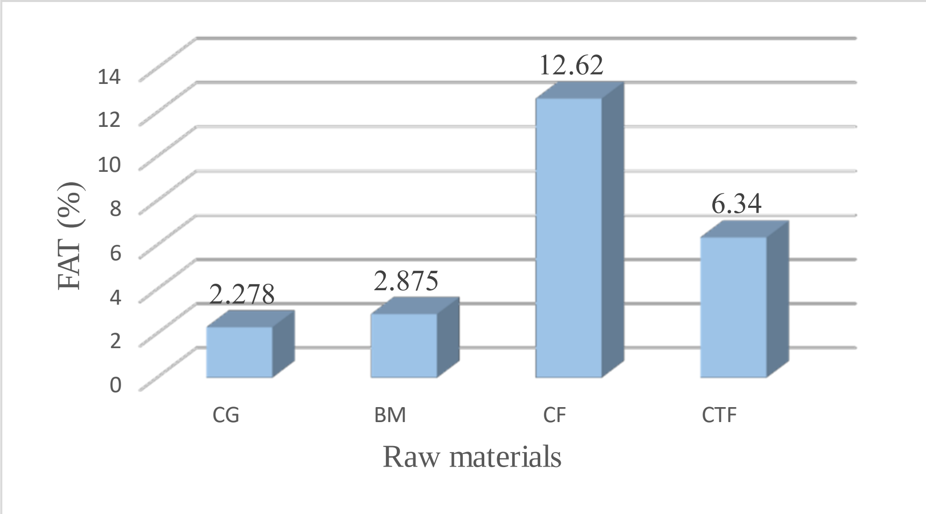


*Corn grits (CG), Barnyard millet (BM), Coconut fibre (CF), Coconut testa fibre (CTF)

Figure 5.1 Moisture Analysis of raw materials

The moisture content of the raw materials is shown in Fig 5.1, corn grits showed the highest moisture content of 5.7%, followed by Coconut testa fiber with 3.7 %. Barnyard millet and coconut fiber had the least amount of moisture about 0.6% and 0.65% respectively compared to others.

5.1.2 Fat Estimation



*corn grits (CG), barnyard millet (BM) coconut fibre (CF), coconut testa fibre (CTF).

Figure 5.2 Fat content of raw materials

The fat content of raw materials is shown in figure 5.2, the fat content shows no significant variation between corn grits and barnyard millet. Corn grits have the lowest fat percentage. Fat content may vary from very low to high, depending on factors including variety, origin, and geography. Coconut fiber shows the highest fat content (12.76%) and coconut teste fiber had about 6.7% of total fat content, as coconut is rich in fat.

5.2 Physio-chemical properties of extruded snack

Table 5.2 Physio-chemical properties of extruded snack

Samples	PHYSICO-CHEMICAL PROPERTIES					
	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Carbohydrate (%)
Control	1.10	3.028	10.493	0.798	1.10	84.58
CF	1.27	3.161	9.851	0.539	10.25	85.18
CTF	1.15	2.998	10.219	0.545	8.95	85.01
CTC	0.76	3.193	10.098	0.561	0.97	85.39

* CF – coconut fiber, CTF – coconut testa fiber, CTC – coconut testa phenolic concentrate

5.2.1 Moisture Estimation

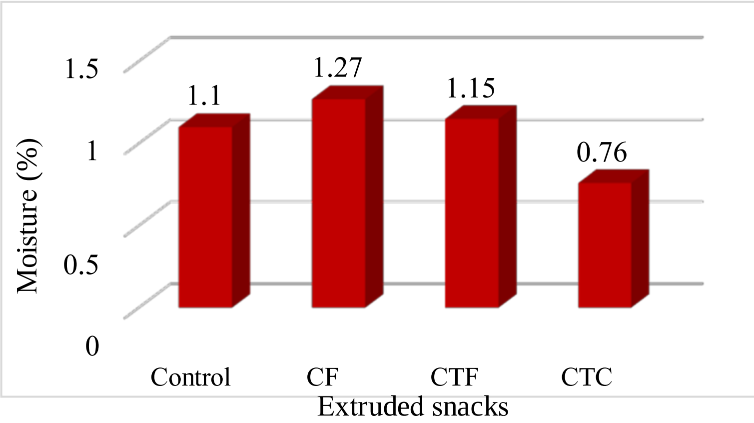


Figure 5.2.1: Moisture analysis of extruded snack

The control comprising corn grits and barnyard millet showed a moisture content of about 1.1%. In the variation containing 5% coconut fiber, the moisture content increased slightly to 1.27%. This suggests that the coconut fibers contain some inherent moisture, contributing to the overall moisture content of the mixture. Whereas in case of coconut testa fibers, the moisture content remains relatively similar (1.15%). This indicates that the moisture content of the product is not significantly affected by the type of coconut fibers used. When coconut testa phenolic concentration is introduced, the moisture content decreases to 0.76%, which suggests that the addition of coconut testa phenolic concentration might have absorbed some moisture from the mixture, leading to a reduction in overall moisture content. The moisture content of the extruded material varies slightly depending on the additives used. Adding coconut fibers has a marginal impact on moisture content while introducing coconut testa phenolic concentration leads to a notable decrease in moisture content.

5.2.2 Total Ash content

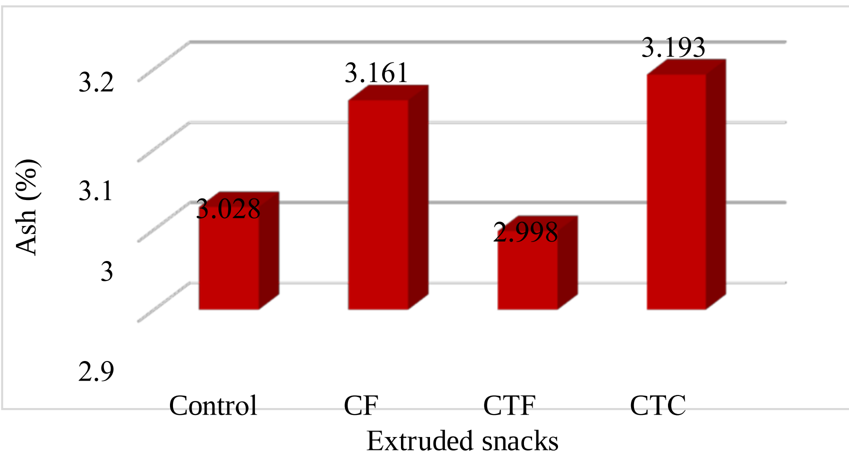


Figure 5.2.2: Total ash content of extruded snacks

Ash content of the control and the variation samples were observed in the range of 2.99 to 3.19%, However, statistically significant differences were observed between each variation. The extrudates made by incorporating coconut fiber (CF) and coconut testa concentrate (CTC) have statistically similar ash content, whereas the control and coconut testa fiber (CTF) incorporated extrudates had statistically different ash content. The high ash content of the extruded snack samples was observed in the variation comprised of coconut fiber, as it is a good source of mineral elements since ash is an indication of mineral element in a food.

5.2.3 Protein Estimation

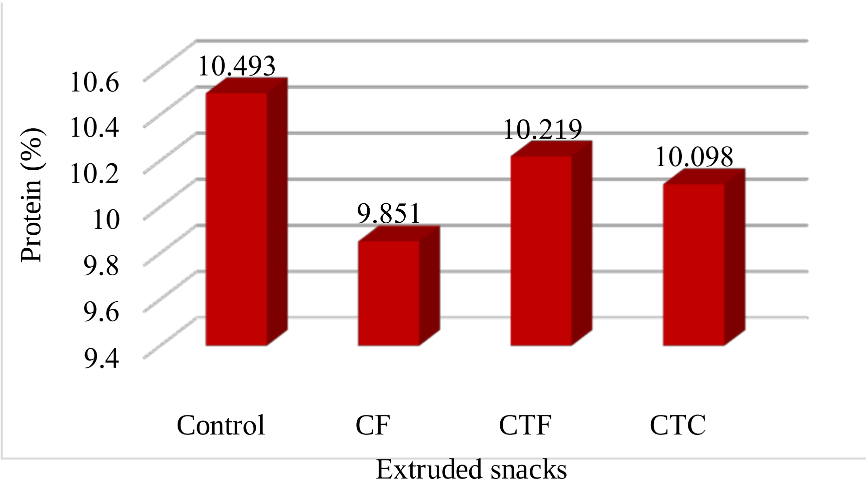


Figure 5.2.3: Protein content of extruded snacks

Protein content was observed to be high in the control sample when compared to the experimental samples. The protein content of experimental samples ranged from 9.85 to 10.49% respectively. The highest protein content was seen in extrudates made from control. The lowest protein content was seen in extrudates made from coconut fiber. In an early report, Ediriweera and Kashizumi (1991) noted that fresh coconut's whole endosperm typically contains about 4% protein and a value that could potentially increase in defatted meals.

5.2.4 Fat Estimation

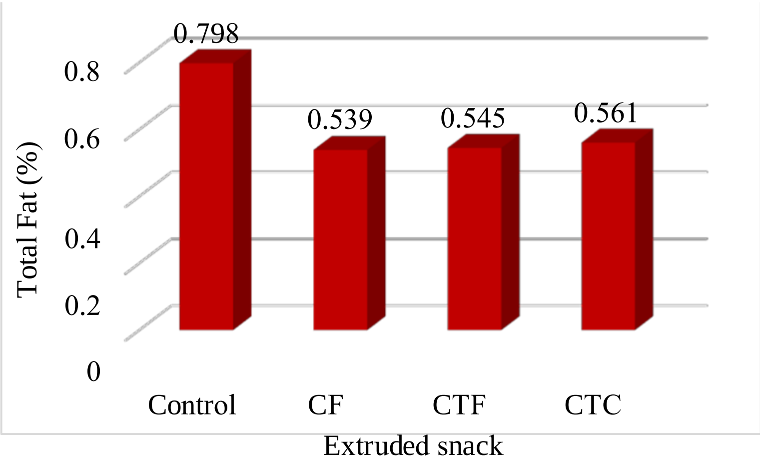


Figure 5.2.4: Fat content of extruded snacks

The fat values were in an extensive range, with the highest value in the control and the lowest in coconut fiber incorporated extrudates. Total fat content is lesser for all extrudates except the control extruded snack. The fat content in the RTE extrudates was due to the seasoning (added oil & spices) in extrudates to improve the palatability rather than the fat content of the raw ingredients.

5.2.5 Estimation of Fiber Content

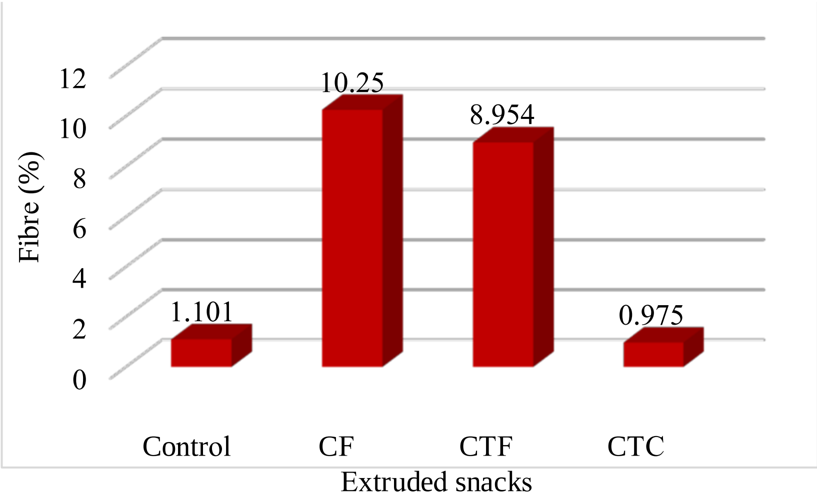


Figure 5.2.5: Fiber content of extruded snacks

Fiber plays a crucial role in extrusion processing by improving the texture, structure, expansion, nutritional profile, and consumer appeal of food products. Its incorporation into extruded foods offers many benefits, ranging from enhanced sensory attributes to improved nutritional value and health outcomes. In crude fiber content, control sample was least compared to the experimental extrudates. The coconut fiber (CF) and coconut testa fiber (CTF) have the highest value, whereas control and coconut testa concentrate (CTC) have the lowest value.

5.2.6 Total Carbohydrate

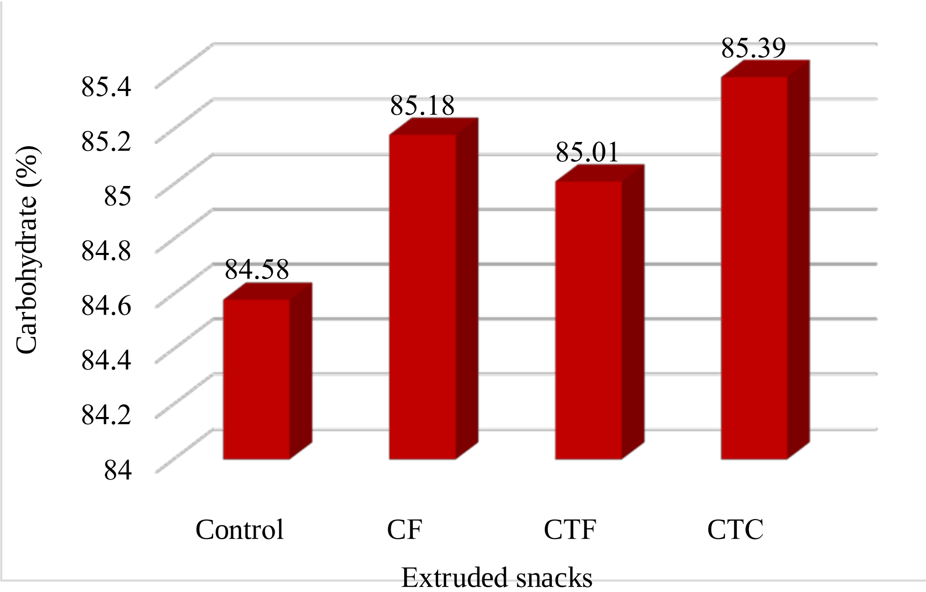


Figure 5.2.6: Carbohydrate content in extruded snacks

The energy value of control was observed to be lower than the other three extrudates, which was found to be about 84.6%. In the case of extrudates with coconut testa incorporated (CTC) coconut fiber (CF), and coconut testa fiber (CTF), no significant difference was observed. Among these coconut testa concentrate has the highest value about 85.4%. All the products meet the desired requirement of being utilized as supplementary food. This indicates that the RTE extrudates can be efficiently utilized as a product for supplementary feeding programs.

5.3 Antioxidant Assay

Table 5.1: Antioxidant assay of raw materials and extruded snack

*Coconut fibre (CF), Coconut testa fiber (CTF), Coconut testa concentrate (CTC)

SAMPLES	Antioxidant Properties	
	TPC (mg/GAEg)	DPPH IC50 mg/ml
Raw Materials		
CF	0.85	0.96
CTF	1.44	0.64
CTC	1.68	0.37
Extruded Snacks		
CONTROL	0.10	0.92
CF	0.07	0.90
CTF	0.54	0.77
CTC	0.76	0.46

Table 5.1 shows the comparison between the extracts of coconut fibre (CF), coconut testa fibre (CTF), and coconut testa concentrate (CTC) with respect to their total phenolic content and radical scavenging activity. For raw materials, TPC ranges from 0.85 to 1.68 GAE (mg) per gram of sample with the highest phenolic content been observed in coconut testa concentrate (CTC), whereas coconut testa fibre had 1.44 GAE (mg) per gram and least amount of TPC was observed in coconut fibre (CF) which was about 0.85 GAE (mg) per gram. In radical scavenging activity, coconut fibre (CF) showed IC50 value of 0.96 radical scavenging activity, whereas in case of coconut testa concentrate, IC50 value of 0.37 radical scavenging activity was observed. For extruded snacks, TPC ranged from 0.07 to 0.76 GAE (mg) per gram, the higher phenolic content was found in the product made up of coconut testa concentrate (CTC) about 0.76 GAE (mg) per gram and the lower phenolic content showed by coconut fibre (CF) with 0.07 GAE (mg) per gram. For DPPH, coconut testa concentrate (CTC) shows radical scavenging activity IC50 value of 0.46 and coconut fibre IC50 value of (CF) 0.90. the value showed that the coconut testa concentrate added product has more bioactivity than others.

5.4 Functional properties of the extruded snacks

Bulk density and Tapped density were determined by filling a 100ml measuring cylinder with the selected extrudates. The cylinder was tapped 12 times till the products measured up to the litres mark and was expressed. These are essential parameters that help in packaging.

Table 5.3 Functional properties of extruded snacks

SAMPLES	FUNCTIONAL PROPERTIES	
	Bulk Density (mg/ml)	Tap Density (mg/ml)
CONTROL	0.50	0.83
CF	0.50	0.80
CTF	0.58	0.90
CTC	0.65	0.83

* CF – coconut fiber, CTF – coconut testa fiber, CTC – coconut testa phenolic concentrate

The functional properties of four extruded products are shown in Table 5.3. The bulk density of control and coconut fibre(CF) showed no significant difference. The highest value was observed in coconut testa concentrate (CTC) due to high moisture content and particle size. And it may be related to the content of their crude fiber. The lesser the bulk density, the more packaging space will be required. This is because the lower the BD value, the higher the amount of flour particles that can stay together, thus increasing the energy content that could be derivable from such diets.

Tap density in the extruded sample coconut testa fiber (CTF) was the highest amount (0.90). The tap density of control and coconut testa concentrate (CTC) were the same followed as 0.83.

5.5 Color analysis of extruded snack

Throughout the extrusion process, various reactions take place that vary the extrudate colour. Colour is an essential attribute because it not only enhances the appearance of products but also serves functional purposes such as identification, safety, and durability, contributing to the overall quality and usability of the end product.

Table 5.4 Colour analysis of extruded snacks

Sample	**L***	**a***	**b***	**ΔE ***
Control	66.11±0.13	2.70±0.10	24.85±0.42	39.87± 0.17
CF	60.60±0.38	6.05±0.50	29.57±0.36	47.44±0.29
CTF	59.80±2.27	4.21±0.14	22.86±0.53	44.02±1.68
CTC	59.39±2.48	6.38±0.41	24.78±0.66	45.64±2.44

* CF – coconut fiber, CTF – coconut testa fiber, CTC – coconut testa phenolic concentrate

The color measurements among different extruders prepared using CF, CTF, and CTC have been analyzed. The 5% of CF, CTF, and CTC-added snack products were not significantly different in brightness. However, the control had the highest brightness than other extrudates. It was observed that extrusion processing at die temperatures of 130 and 170 °C caused a significant decrease in the brightness at all levels of CF, CTF, and CTC addition. It is known that reducing sugars and proteins (amino acids) in foods can react under high processing temperatures to promote non-enzymatic browning (Maillard reaction), which results in darkening of the final product. CF, CTF, and CTC are high in sugars and protein (amino acids). Therefore, the decrease in brightness may be attributed to the Maillard reaction as a consequence of extrusion processing.

Colour difference (ΔE*) was used to represent the colour change between the unprocessed and processed flours (effect of processing). In this study, the values of Δ*E** for all the extrudates increased significantly as the processing temperature increased from 130 to 170 °C. The values of Δ*E** for the extrudates formulated with 5% of CF, CTF, and CTC were increased compared to the control. These results suggested that the colour in the CF, CTF, and CTC, along with processing temperatures, had a direct effect on the values of Δ*E**.

5.6 Texture analysis of extruded snack

The physical properties of the Extruded snack were evaluated using Texture Profile Analysis. The extrudate's textural properties were determined using the double compression method with the applied force on the extrudates to break. Texture is one of the most important quality features of extruded products, which easily drives consumer preference.

Table 5.5 Texture analysis of extruded snacks

Samples	Hardness (N)	Cohesiveness (%)	Springiness (%)	Chewiness (%)	Gumminess (%)	Fracturability (%)
Control	4.55 ± 0.00	0.04 ± 0.04	0.05 ± 0.05	0.01 ± 0.01	0.19 ± 0.20	3.19 ± 1.23
CF	4.39 ± 0.28	0.01 ± 0.01	0.03 ± 0.01	0.00 ± 0.00	0.03 ± 0.03	3.91 ± 0.50
CTF	2.63 ± 0.00	0.04 ± 0.02	0.05 ± 0.01	0.01 ± 0.00	0.12 ± 0.06	3.11 ± 1.68
CTC	5.19 ± 0.28	0.02 ± 0.02	0.03 ± 0.01	0.00 ± 0.00	0.12 ± 0.11	2.23 ± 0.50

* CF – coconut fiber, CTF – coconut testa fiber, CTC – coconut testa phenolic concentrate

Hardness, which reflects the force required to compress the snack, there are no significant differences in hardness between control (4.55), CF (4.39), and CTC (5.19) compared to CTF (2.43) due to the addition of coconut testa fiber and it's related to the expansion and structure of the product. Fracturability, a measure of the snack's brittleness and crispiness of the extrudates, here control (3.19) and CF (3.91) and CTF (3.11) was found to be significantly similar range, whereas CTC has lower Fracturability comparatively (2.23), due to the incorporation of coconut testa concentrate which indicates its resistance to break. The texture is important in extruders as it affects consumer satisfaction, product differentiation, structural integrity, expansion and puffing characteristics, and mouthfeel of extruded food products. Manufacturers must carefully consider and control texture parameters to meet consumer expectations, and market demands effectively.

5.7 Sensory Analysis

Table 5.6 Sensory analysis of extruded snacks

ATTRIBUTES	CONTROL	CF	CTF	CTC
Colour	8.32±1.73	8.08±2.83	5.80±2.84	7.9±2.50
Surface Uniformity	9.11±3.05	6.01±2.65	6.18±2.63	9.21±3.47
Uniformity of Pores	6.86±2.48	6.94±2.67	7.23±2.75	7.12±3.71
Crunchiness	8.98±3.33	8.67±2.80	9.4±2.23	9±3.90
Hardness	8.29±2.56	7.86±3.08	8.34±4.13	8.20±3.49
Chewiness	7.2±3.24	8.87±3.50	8.95±4.04	7.23±3.97
Mouthfeel	8.25±3.51	6.82±3.32	7.04±3.61	9.02±3.82
Fibery	6.77±2.86	8.23±3.28	8.60±3.71	6.01±1.97
Salty	7.30±2.93	7.41±2.88	6.48±3.62	8.14±3.41
Spicy	8.30±3.08	7.36±3.05	6.24±2.95	8.28±2.89
Woody	5.27±2.29	6.21±3.53	5.51±2.97	6.68±3.18
Off Taste	3.09±3.14	3.27±2.64	3.51±3.88	4.91±4.43
Overall Acceptability	10.25±3.12	9.76±22.57	10.6±2.33	8.71±3.02

* CF – coconut fiber, CTF – coconut testa fiber, CTC – coconut testa phenolic concentrate

Sensory analyses of extruded snacks:

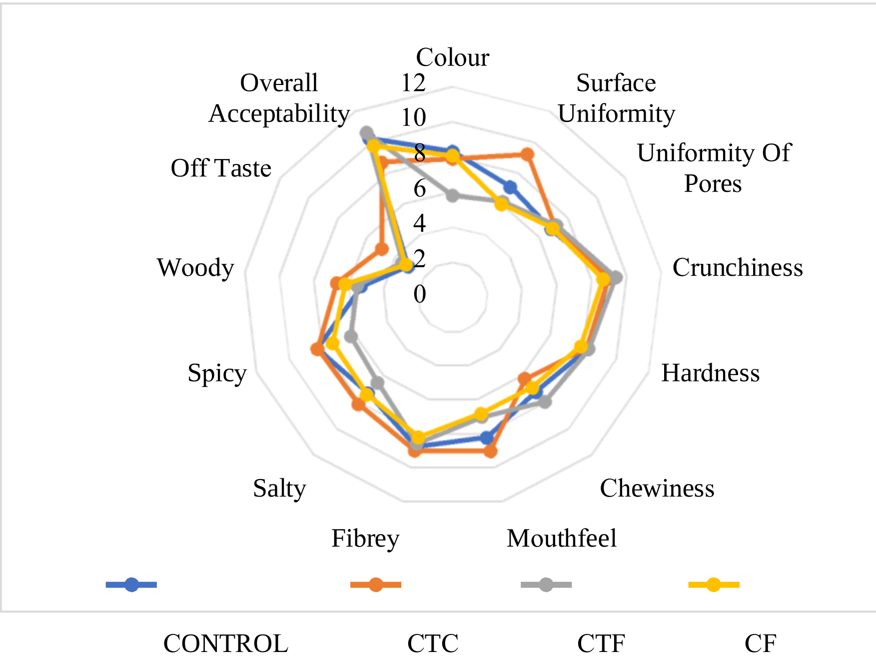


Figure 5.8 Sensory analysis

Table 5.6 shows the sensory analysis of extruded snacks. The sensory evaluation of standardized extruded snack was assessed using 15-point hedonic rating scale and evaluated on the basis of several sensory attributes. In case of colour, there is no significant difference in the acceptance level in control, coconut fiber (CF), coconut testa phenolic concentrate (CTC), whereas coconut testa fibre(CF) seemed least accepted due to the addition of 5% of coconut testa fiber (CTF) resulted in reduced brightness of the product colour. The surface uniformity of coconut testa concentrate (CTC) was similar to control, whereas the coconut fiber (CF) and coconut testa fiber (CTF) varied according to the fiber content. Crunchiness and hardness were the important parameters that can be seen in the sensory attributes of extruded snacks. Coconut testa fibre(CTF) shows more crunchiness and hardness, whereas it shows a more fibery and chewy nature in coconut testa fiber (CF) due the presence of insoluble fibers. The overall acceptability of all the extruded snacks ranged between 10.6 to 9.8 except CTC snacks as it's made up of 5% coconut testa concentrate which gives the product an astringent flavor and off taste, leading to a decrease in the overall acceptability of the snack. By reducing the incorporation level of coconut testa concentrate in the extrudates, the astringency, and off taste can be reduced, which helps in improving the consumer's acceptance level significantly.

CONCLUSION

The extruder with enrichment of CTC, CTF, and CF has provided valuable insights into the potential utilization of these coconut by-products in food processing applications. Through this study, several significant findings have emerged. Incorporating CTC, CTF, and CF into the extruded products has significantly improved their nutritional profiles and functional properties. These by-products are rich sources of dietary fiber, phenolic compounds, and other bioactive components, which are known to impart various health benefits, including antioxidant and antimicrobial properties. The addition of CTC, CTF, and CF has influenced the texture and structure of the extruded products. The presence of dietary fiber and other insoluble components has increased bulkiness and improved textural characteristics, such as firmness and chewiness, enhancing the overall eating experience. The utilization of coconut by-products has also enhanced the colour and flavor attributes of the extruded products. The inherent colorants and flavor compounds present in coconut testa phenolic concentrate and coconut fiber have imparted characteristic hues and taste profiles, enriching the sensory appeal of the final products.

Their ability to improve nutritional value, texture, color, and flavor makes them promising applicants for uses in a variety of food products, including extruded snacks, breakfast cereals, and baked goods. By valorizing coconut by-products, such as CTC, CTF, and CF, this study contributes to sustainable practices in the food industry. It offers a viable solution for using agricultural waste materials, thereby reducing environmental impact and promoting circular economy principles. This study emphasis the potential of these by-products as valuable ingredients in food processing. Further research and development efforts in this direction could create innovative, nutritious, and sustainable food products that meet consumer demands for healthful and environmentally friendly options.

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