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DEVELOPMENT OF BANANA STEM, CHICKPEA PLANT BASED MEAT

Dr. M. Niharika[1] Dr. D. Madhavi [2] Dr. G. Sireesha[3]* Bhargavi Savalapurapu[4]

[1, 2] Assistant Professor, Department of Home Science, Sri Padmavati Mahila Visvavidyalayam, Tirupati, Andhra Pradesh, India

[3] **Corresponding Author**, Assistant Professor, Department of Home Science, Sri Padmavati Mahila Visvavidyalayam, Tirupati. Email: sireeshaguttapalam@gmail.com,

[4.]Junior Research Fellow, Department of Home Science, Sri Padmavati Mahila Visvavidyalayam, Tirupati, Andhra Pradesh, India

ORCID IDs
Dr.M.Niharika- https://orcid.org/0000-0002-9471-2759
Dr.D.Madhavi- https://orcid.org/0009-0008-1023-1765
Dr.G.Sireesha- https://orcid.org/0000-0001-7351-2566
Bhargavi Savalapurapu - https://orcid.org/0009-0005-0181-5417

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ABSTRACT

Plant-based meat (PBM) is gaining attention due to environmental, health, and welfare concerns. Food Structure methods like extrusion and shear cell are studied, along with improvements in appearance, flavor, safety controls, and protein sources. In order to develop protein based meat replacement with a rich fiber food; this current study we used banana stem, chick peas, Psyllium husk and binding as tapioca flour, spice ingredients for developing a BCPM (Banana stem, Chickpea Plant based Meat). The plant based meat was developed by extrusion and solar drying technology. The proximate composition and sensory analysis of the developed three samples (T1, T2 & T3) were studied; among these three variations T3 showed good sensory acceptance in sensory analysis. The functional properties of developed meat analogue variation 2 and 3 having good water holding capacity. On the other hand it contains 263 kcal of energy, 58.5 gm of carbohydrates, 17 gm of Protein, 5 gm of fat, 16 gm of fiber , 3.8 % moisture, and 99 mg of calcium; when compared to traditional animal meat the developed plant based meat analogue was good in energy, carbohydrate and calcium content. The morphological and textural studies of plant-based meat exhibit comparable characteristics to the available animal meats. Shelf life studies was carried out up to 4 months with different time intervals; the total bacterial counts of developed BCPM is at the end of the best before date varied greatly from below 1.8, it indicates no microbial spoilage was noticed during the storage period. The study emphasized that chick peas, banana stem and Psyllium husk combination would make a suitable plant based meat.

INTRODUCTION

Although red meat can be a good source of nutrients, consumin g an excessive amount of it has been associated with a higher r isk of developing certain chronic diseases because it contains more saturated fatty acids and cholesterol [1]. Meat production is one of the causes by influence the environment: we chop down of forests to create grazing and agricultural area to fulfil the need for animal feed. In addition to being a significant producer of pollutants and greenhouse gases (GHGs), animal husbandry can exacerbate global warming in areas with high water resource demands.

Products made from beef, hog, and chicken are in great demand worldwide; the US and Australia are the countries with the biggest yearly meat consumption [2]. The last 20 years have witnessed a 58% increase in the world's demand for meat due to population expansion and rapid economic development [3]. Global meat consumption exceeded 320 tons in 2018 [3], and the OECD/FAO (2018) expects a 15% increase in the market by 2027. However, in recent years, questions have been raised concerning meat production's inefficiencies in comparison to crop harvesting, as well as the adverse impacts of meat consumption on human health [4, 5]. Food businesses are searching for methods to provide meat substitutes manufactured from nonanimal proteins to consumer markets that resemble conventional meat in terms of appearance, texture, and scent [6, 7]. This is because these concerns are growing. The food research community is currently investigating two major types of meat analogues: culture-based meats (also known as clean meat or in vitro meat) [8, 9] and plant-based meat, which is made from proteins extracted from plants using appropriate structuring processes.

Novel research studies and review articles highlighting various perspectives on the issue of plant-based meat alternative (PBMA) have been written since it has become one of the most popular topics in the academic world. [10] For instance, provided an overview of the major technical advancements for plant-based meat substitutes, emphasizing the structural procedures.

1.2. DRIVING FORCES FOR PBMA DEVELOPMENT: ENVIRONMENTAL AND HEALTH CONCERNS

The expansion of PBMA is driven by the need to meet protein needs, prevent hunger, and solve health, environmental, and animal welfare concerns associated with traditional meat production. This is because animal protein is limited in developing countries. [11,12,13,14]

1.2.1 The environmental concerns of traditional meat production

The substantial energy loss during animal growth and development through ingestion or excretion makes traditional meat production intrinsically unsustainable. According to life cycle assessment studies and other sources, this leads to higher requirements for phosphate rock, water, fossil fuels, and land use than diets containing protein derived from soybeans. [15]

According to research, the animal product that uses the greatest resources, beef, is the main cause of global warming. Research indicates that compared to ruminant meats like beef and lamb, the production of legumes results in substantially lower greenhouse gas emissions. Vegan diets can lower land demand by 50%–60% and emissions by 25%–55%. Compared to animal-based food, plant-based foods emit fewer greenhouse emissions [16].

1.2.2 The associated health concerns of traditional meat intake

The International Agency for Research on Cancer of the WHO has acknowledged that traditional meat intake has caused health concerns since it may be carcinogenic. Cattle and other red meat have also been connected to cancer. Epidemiological research and meta-analyses assess the health effects of eating meat. Risks include elevated risk for esophageal and stomach cancer. [17,4].Plant-based proteins have been associated in studies with a decrease d risk of type 2 diabetes, heart disease, and stroke. A switch to a plant- based diet could lower the death rate by 6% to 10% worldwide. By offering comparable taste and advantages to meat, PBMAs can assist meat eaters in altering their dietary patterns. [18]

1.2.3 The animal welfare concerns of traditional meat production

Stressful situations during treatment, transit, and slaughter are among the animal welfare issues in traditional meat production that are addressed by the World Organization for Animal Health (OIE). They support plant-based substitutes for the production of meat because they think it is unethical to raise and slaughter animals. [13]

1.3. HISTORY OF PBMA DEVELOPMENT:

Since ancient times, imitation meat or plantbased meat substit utes have been produced and used.Ancient people produced m eat substitutes including seitan, tempeh, and tofu. Tofu, a traditional meat alternative, was consumed in Tang and Han dynasties in China which could have made its way to Japan in the late Tang or early Song periods.

Later in the early 20th century, to promote health, pioneers such as John Harvey Kellogg created nut and cereal-based products such as Nuttose and Protose. Dry TVP's, made from extruded defatted soy meal, soy protein concentrates, or wheat gluten and also appeared.

Following the years, following World War II, the production and packaging industries achieved substantial advances in plant protein concentrates, isolates, and textured proteins, which aided the development of soy-based meat replacements. In the United States, niche vegetarian goods such as Tofurky appeared in 1980 to address rising meat consumption. The demand for beef substitutes has increased in 2002 as peopl e's awareness regarding environmental and health issues has gr own. New products such as Impossible Burger and Byeon Burger usher in a new era of plant-based meat alternatives, rising in the sector. Modern food science and manufacturing breakthroughs have resulted in the development of plant-based meat alternatives that have the same taste, texture, look, and usefulness as traditional sausages, burgers, and fillets. [19]

1.4 Plant Proteins

Among the macronutrients, proteins are thought to be essential for sustaining the healthy development of muscles and tissues as well as for constructing new ones. Animal proteins make up the majority of the proteins consumed by humans, but the trend toward a healthier options has given insight to sources of plant-based protein. Plant-based protein sources can be categorized into many types based on where they come from: (1) legumes (peas, beans, peanuts, sunflower, rapeseed, sesame, soybeans); (2) cereals and pseudo-cereals (quinoa, amaranth, buckwheat, maize); (3) oil seeds (rapeseed, sunflower,hemp, sesame) ; and (4) algae. Therefore, it is possible to create meat substitutes with the appropriate texture and mouthfeel by using some of the previously indicated groups (such as legumes and grains) [20]. However, other groups typically serve as an excellent sources of amino acids and bioactive peptides[21].In addition, seeds can serve as a source of fats—which are required for maintaining texture, taste, mouth feel, and juiciness—as well as fat-soluble vitamins and fatty acids [22]

1.4.1. Legumes as Protein Sources

Legumes are plants with a high nutritional value that are members of the Fabaceae family. They are abundant in fibre, minerals, antioxidants, and proteins (20–30%). Some members of the group that will be covered in this subsection include soy, lentils, peas, chickpeas, beans, and peanuts.

1.4.2. Peanuts, Peas, Chickpeas, Lentils, and other Beans

Peas are another type of plant in the Fabaceae family; they come in garden and field pea types, among others. In addition to a significant amount of vitamins and minerals, green peas contain 20–50 grams of the starch, 17–22 grams of carbohydrates, 14–26 grams of dietary fiber, 6.2–6.5 grams of protein, 0.4 grams of fat, and 1g/100 g of ash. They have a low glycaemic index, are high in lysine and threonine, and offer several health benefits, including cancer prevention and treatment [23]. Pea proteins are significant from a technical perspective because they have the ability to stabilize foams and create gels and emulsions. However, because their gelling capacity is substantially lower than that of soy proteins, the mixes must be treated with salts or structural agents to produce gels with the same structural features as those generated from soy proteins [24, 25]. The components in soy that enhance its water-holding, gelling, and fat-absorbing properties, as well as the higher protein unfolding grade of soy proteins after processing, are responsible for soy's greater gelling capacity than pea [26]. Pea proteins have poorer gelling qualities, but they are nevertheless advantageous since they are more widely available, can be farmed in temperate temperatures, are less allergic than soy, and are not associated with genetically modified organisms. As with soy, pea proteins can be textured to create fibrous structures or utilized as isolates.

1.4.3. Chickpea

Chickpea has been recognized as well as utilized in food items since antiquity, currently it is seeing a surge in popularity as consumer requirements and requests change slowly but gradually toward plant-based diets. Its advantages also include the absence of phytoestrogens and allergenicity. A powdered isolation of chickpea proteins with a high amino acid score and all the necessary amino acids can be employed [27]. Proteins such as globulin, albumin, prolamin, and gluten are known to be abundant in it [28]. The main difficulty with the protein present in chickpea is their inadequate solubility and the dependency of their functional qualities (gelling behaviour, foaming ability and emulsification) on the pH of medium, which limits their use in food preparation. Nevertheless, by modifying proteins by heat, mechanical action, or enzymatic treatment, these challenges can be addressed. The functional and thermal properties of Indian chickpeas were studied by [29]. The foaming capacity of the beans, which ranged from 30.4 to 44.3%, was found to be substantially lower than the foaming capacity of the soy protein isolates, which was 235%. This is due to globulins, which are present in a significant amount of the beans and are resistant to surface denaturation. On the other hand, foams made with chickpea proteins had a rather high level of stability (94.7% after 120 minutes of storage). Additionally, it was found that the gelling capacity ranged from 14 to 18%, which is comparable to the range seen in isolates of soy protein (16–17%). In contrast to soy protein isolates, chickpea protein isolates have larger capabilities for binding water and oil, and because they include carotenoids, they may also be utilized to improve the colour of meat analogues, as reported by Kumar et al. [30].

1.4.4. Banana Stem: One of the most useful plants in the world is the banana plant. You may utilize almost every part of the plant, including the fruit, peel, leaves, stalk, pseudo-stem, and inflorescence (flower). Monocotyledonous plants, bananas are members of the order Zingiber ales, family Musaceae, and genus Musa. Research revealed that M. acuminata's phenolic compounds have a major role in its wide range of pharmacological properties, which include a number of therapeutic applications. Bananas provide a number of health advantages. This is because, as noted by [31], bananas help the body retain calcium, nitrogen, and phosphorus—all essential for the growth of strong, reparable tissues.

The pseudo stem of banana has been traditionally used to cure a variety of conditions, such as diabetes, gout, nephritis, diarrhoea, sprue, intestinal lesions in ulcerative colitis, uraemia, and heart disorders. Flowers are used as a therapy for menorrhagia and dysentery. The stem of the fruit plant is used to cure diarrhoea, dysentery, cholera, otalgia, and haemoptysis; the blossom is used to treat menorrhagia, diabetes, and dysentery. The root is used as an anthelmintic and to treat blood irregularities and sexual diseases. Additionally, the plant is used to treat snakebites, discomfort, and inflammation [32].

The pseudo stem of a banana has relatively little fat (0.98%), hence fats do not considerably contribute to the energy content. The banana pseudo stem has around 46.58%, 7.34%, and 21.06% of carbohydrates, protein, and starch, respectively. Pseudo stem has a total dietary fibre content of 61.14%, of which the percentages of soluble and insoluble fiber (IDF) are around (02.04%) and (59.10%), respectively [33]. By extending the period of time food stays in the stomach, high-dietary fiber diets effectively provide early satiety signals and reduce the incidence of stomach ulcers.

1.4.5. Psyllium Husk (Plantago Ovata)

Psyllium, or Plantago ovata, has strong water absorption and gelling qualities, making it a natural source of dietary fiber [34,35]. According to [36], this indicates that it has functional potential as a hydrocolloid in the manufacture of novel foods. Additionally, psyllium has been linked to numerous health benefits for conditions like diabetes, constipation, colon cancer prevention, diarrhea, irritable bowel syndrome (IBS), abdominal pain, obesity, and hypercholesterolemia [36,34]. It is a trade crop grown in Iran, Pakistan, and India that is crucial to the economy. India possesses a near-monopoly on the global export of seed and husk [37].

Polysaccharides such as pentoses, hexoses, and uronic acids make up psyllium. According to[38], husk preparations typically include 67–71% soluble fiber and around 85% total fiber by weight, while seed preparations have about 47% soluble fiber by weight.

In present research, researches employed Extrusion technique and solar drying for production of a meat, where they used chickpea, banana stem and psyllium husk, Tapioca flour and spices. The aim of this study is to ascertain and examine the generated PBMA product's shelf life, proximate and sensory analysis.

2. MATERIAL AND METHODS.

2.1 Raw material: A chickpea, banana stem, and Psyllium husk were used to create a meat substitute. Tapioca flour and spices were purchased from a nearby Tirupati market.

2.2 Extruder

There was just one screw extruder used for the extrusion process, the extruder was configured at 100 rpm.

2.3 Preparation method

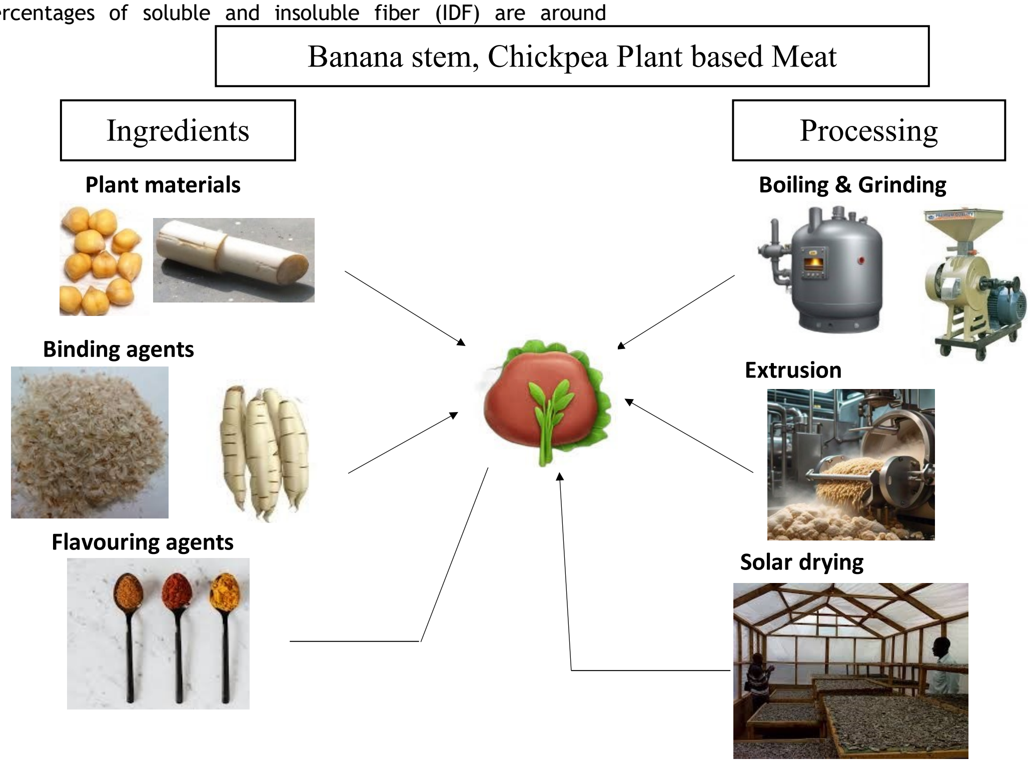


Fig-1 Shows the Research design of the development of BCPM

A blend of chickpeas, psyllium husk, banana stem, tapioca flour, and spices was used to produce a meat substitute. Different formulations were tried and from that three formulations were selected and presented in the table (1). Chickpeas were soaked for a whole night, then cooked and ground into a fine paste that was set aside. The banana stem was chopped into 1-centimeter cubes. The banana pieces were then blanched for one minute in water at 100° C, cooled, and ground into a paste. After making dough using chickpea and banana stem paste, adding the additional ingredients (Psyllium husk, Tapioca flour and spices) and putting the dough through an extruder to texturize it, the dough was ready. The temperature was maintained at room temperature and the extruder speed was set at 100 RPM during the extrusion process. After that, the extruded strips were cut and dried in the solar cabinet, which has been built which is appropriate for drying goods that need to be at their ideal temperature between 37 and 40 ° C and then after drying, the pieces were stored at room temperature. Fig.2 shows the variations of the developed BCPM

Table 1: Three Formulations of developed Banana stem, Chickpea Plant based Meat

Ingredients (g)	Variations-1	Variation -2	Variation -3
Banana stem	35	30	25
Chick peas	25	30	35
Psyllium husk	20	20	20
Tapioca flour	15	15	15
Spices	5	5	5
Total	100	100	100

V1 V2 V3

Fig 2: Variations of the developed Plant Based Meat Analogue

2.4 Proximate analysis

The meat analogue was subjected to moisture and protein analysis in accordance with AOAC 2000 methods (950.46B) and (981.10). Additionally, fat was treated according to the guidelines in the AOAC 1995 (960.39A). The protocol that was used for ash content was (920.153) AOAC 1990. Furthermore, Weendes procedure (978.10) AOAC 1995 was adhered to during the fiber analysis.

2.5 Sensory and Textural Evaluation of Product

To measure acceptability, nine-point hedonic measures were used. The exam known as the hedonic rating scale allowed judges to express their assessment scores based on the ratings assigned to each sensory feature on the accompanying score card. Ten seasoned members of the panel took part in the product's sensory assessment. A distinct column was provided for writing comments, according to the changes made to the final output. The panel members were given instructions prior to the product being exposed to a sensory evaluation for each trial. Each trial's score card was provided individually. [39,40]

2.6 Functional Properties

The functional properties constitute the fundamental physicochemical characteristics of food that represent the intricate relationships between the compositions, structures, and physiochemical characteristics of food components. Functional characteristics also include how components react while being prepared and cooked, as well as how they impact the final product's appearance, texture, and flavor. In addition to gelatinization, bulk density, dextrinization, pres ervation, denaturation, coagulation, formation of gluten, jellin g, shortening, plasticity, flakiness, moisture retention, aeratio n, and sensory qualities, functional properties also include swe lling ability, oil and water absorption capacity, emulsion activit y, stability, and foam capacity. [41].

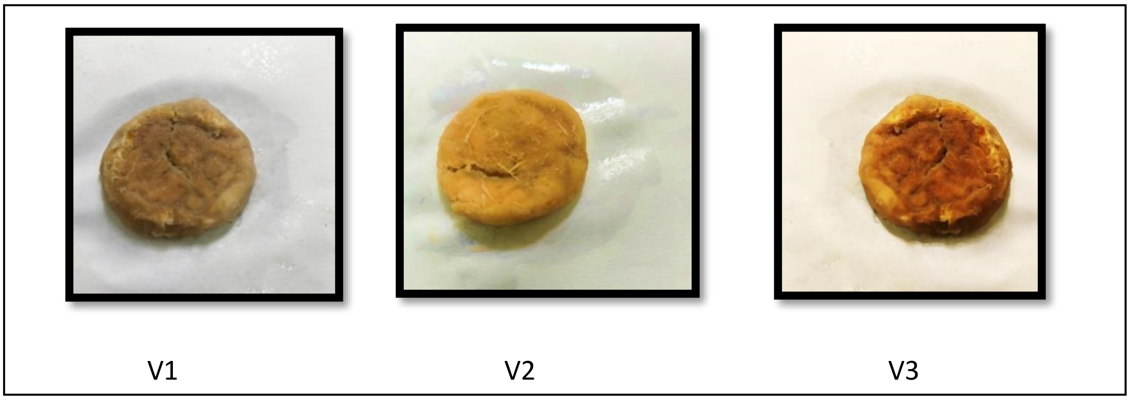
2.6.1 Cooking yield

The cooking yield of Banana stem, Chickpea Plant based Meat (BCPM) were determined by measuring the weight of each variation and determining the difference in weight between before and after cooking. To estimate the cooking yield of Banana stem, Chickpea Plant based Meat (BCPM) patties, we measured the weight of variation and calculated the difference in weight before and after cooking. The following equation is used to determine the cooking yield of the developed BCPM's. [42]

Cooking yield= wt of cooked BCPM / wt of raw BCPM X 100

2.6.2 Release water percentage

The release water percentage was calculated using compression on the BCPM with a weight of 2kgs for all variations and triplicate was done. 4gms sample of each variation has been taken on a filter paper with two plastic sheets wrapping the meat and the filter paper and a weight of 2kgs was imposed on the samples for 5min. After removing the weight from the samples, they are immediately weighed to calculate the release water percentage. [43] . Fig 3 represents the water release & cooking loss percentage of the developed meat analog.



2.6.3 Cooking Loss percentage
The samples were weighed initially and then cooked in a water bath for 5min, cooled and then sample was weighed. By using the initial weight as W1 and final weight as W2, the cooking loss percentage was calculated using the formula.
100 X W1-W2/W1 [44]

2.7 Morphology studies of the Plant Based meat analogue
A scanning electron microscope (SEM) was used to investigate the morphology of dried plant-based meat samples. The samples were mounted on the specimen holder, sputter-coated with gold palladium and examined at 15 kV and a vacuum of 9.75 × 10−5 torr. The magnification of 100X was used for studying the morphological structure of the plant based meat analogues. [45]

2.8 Microbial Analysis
Standard procedures were used to examine the bacterial extracts and Total Plate Count (TPC) of the meat samples that were preserved in plant-based storage. The method of dilution plate may be used to assess the shelf life. The most popular approach for counting the number of live microorganisms in samples is the dilution plate count technique, which may also be employed as an additional technique. The technique is predicated on the idea that microorganisms will separate from the sample when agitated in a suitable liquid at a known weight. Each detached cell will then form a distinct colony when plated on a nutrient medium (Dextrose tryptone Agar medium) in a petri dish. [46]

3. RESULTS AND DISCUSSION:

3.1 Sensory Analysis

Table -2: Mean sensory scores of the Banana stem, Chickpea Plant based Meat

Sensory and textural Attributes	Trials		
	V1	V2	V3
Color	5.1±0.82	5.3±0.73	6.8±0.0
Taste	5.5±0.71	6.3±0.67	6.9±0.32
Flavor	4.23±0.47	5.4± 0.52	6.2± 0.42
Firmness	5.9 ± 0.2	6.0±024	7.0±0.12
Elasticity	6.2±0.14	5.6±0.41	8.1±0.34
Tenderness	4.9±0.41	5.6±0.31	8.5±0.12
Chewiness	7.30±0.21	4.0±0.50	7.0±0.24
Gumminess	6.53±0.41	5.4±0.14	8.4±0.31
Overall acceptability	5.1±0.57	4.9±0.32	7.1±0.43

Colour: The colour evaluation of the created product is shown in the table.2. The T3 had the highest mean score of 6.8, which was followed by the V2 (mean score of 5.3) and the V1 (mean score of 5.1). [47] said that golden brown is the perfect colour for a flavourful imitation of cooked meat.
Taste: V3 had the highest mean score of 6.9, followed by V2 with a score of 6.3 and V1 with a score of 5.5. The new product's preparation involved the incorporation of Psyllium husk, spices, and variable proportions of chickpea and banana stem.
Flavour: The mean scores for each sample's flavour are displayed in Table 2 of the findings tabulated. According to the analysis, variation 3 had an acceptable taste. Banana stems consist of both soluble and insoluble fibers, with the core being rich in polysaccharides and trace elements and having a low lignin concentration, indicating that the fiber has a neutral flavor. according to [48].
Texture: Texture is one of the most important variables affecting consumer perceptions of meat analogue goods. The textural parameters including firmness, elasticity, tenderness, chewiness and gumminess, developed meat analogue in Table 2. It was reported that the textural parameters scored high in V3 compared to other trials because the chickpea and banana stem quantity were high in the trial 3; Psyllium husk is having good water holding capacity. Hardness, cohesiveness, chewiness, and gumminess all decrease with increasing moisture content, according to research on the rheological characteristics of soy protein Mas [49]. The presence of myofibril proteins in meat, which create a harder network formation inside and increase resistance to compression, is most likely the cause of the higher values for hardness, chewiness, and gumminess found in beef and pork [50].
Overall acceptability: According to [51], there are three main factors that determine food acceptability: texture, appearance, and flavour. The mean scores for overall acceptability for each variation sample are displayed in table 2 of the results. Variation 3 in the data had the highest mean score of 7.1 and was deemed to be very satisfactory. [52] claims that the fiber-containing elements in the product are hardly noticed by customers and really enhance the flavour, texture, and stability of the finished good. In the present study Variation 3 was more acceptable than

2 due to the composition, 3 contain more chick pea than V1 and V2. It means chick pea increased the quality of the meat analogue.

3.2 Proximate analysis

The created product's proximate analysis was carried out using the AOAC's standard techniques, and the table 3 shows the results.

Table 3: Nutrient analysis of the 100 Banana stem, Chickpea Plant based Meat.

Nutrient component (g)	Trials		
	V1	V2	V3
Energy(K.Cal)	222	237	263
Carbohydrates (g)	57.8	58.6	58.5
Protein (g)	16.1	16.9	17
Fat (g)	4.6	4.8	5
Fiber (g)	15.9	16.2	16
Moisture	2.5	3.0	3.8
Phosphorus (mg)	80	90.2	103.5
Potassium (mg)	141.1	172.9	192.10
Magnesium (mg)	14.6	16.5	18.60
Calcium (mg)	81	91	99
Ash (mg)	2.5	2.0	2.2

Energy: The table that is included no. -3 show that variation 3 had higher energy content i.e 263 K.cal than the other two paths. In terms of energy, plant-based meat products often give fewer calories per serving than traditional animal meat competitors, which include more fat, particularly saturated fat. This is particularly relevant if the plant-based meat is prepared from leaner ingredients and contains less fat. Plant-based meat may contain fiber from plant sources, leading to a sensation of fullness and satisfaction while adding little calories.

Carbohydrate: Sample V3 had greater carbohydrate content (58.5 grams) than the other two samples. Thus, the plant-based meat that has been created with chickpeas is of superior quality and high in carbs. In meat analogues, starch is the main carbohydrate that helps produce fibrous structures; nevertheless, it shouldn't be more than 10% of the mix. Its primary function is that of a binding agent, changing the structure of the extradite by gelation and disintegration during extrusion. [53]. Sugars are reduced and amylopectin is broken down as a result of extrusion. Following the breaking of hydrogen bonds and primary and secondary valence bonds between adjacent to starch molecules, the subsequent porous and spongy product could enhance the interaction with amylase, hence significantly boosting starch digestibility. [54,55].

Protein: The meat analogue has a high protein level of 17 gm (V3) and a low of 15.1 gm (V1), indicating optimal protein content. This shift was noted as a result of variations in the raw component composition. The other components have lower protein contents than the chickpea, which has a high protein value. Plant-based proteins are mostly found in beans, fruits, vegetables, grains, nuts, and seeds. Soybeans, peas, and wheat gluten are commonly used in plant-based protein products due to their accessibility, affordability, and processing techniques [56]. Following extrusion processing, a number of factors including moisture content, screw speed, feed rate, and cooking temperature might impact how functional plant proteins are. Homogenization, heating, and separation are steps in the production of plant-based meat; heating can change the interactions and structures of plant proteins [57].

Fat: The produced meat analogs fat level was 5 grams, and there isn't much of a difference between the three varieties. Lipids preserve product softness, juiciness, texture, and flavour release and give nutrition and energy [58, 59]. Plant-based meat gains more colour, softness, nutritional value, and structural integrity when lipids are added [60]. Plant-based meat substitutes contain lipids such as coconut, sesame, rapeseed, and olive oil. According to research by [61], adding 3.5% sunflower seed oil to plant-based fish balls enhanced their smoothness and ability to hold water. Two reasons were the improved water-holding capacity and greater flexibility, as well as the improved interaction between hydrophobic amino acids and the hydrocarbon side chains of plant oil [62].

Lipids influence the texture, nutritional value, and sensory characteristics of the product during extrusion by emulsification and plasticization, giving the extruded goods the right texture and viscosity [63]. Lipids and proteins can interact during the extrusion process via covalent bonds, van der Waals forces, electrostatic interactions, and hydrogen bonds. Complexes involving lipids and starch can develop. Lipids can also stop lipases in raw materials from doing their job, which stops free fatty acid production and enzymatic lipid oxidation [64]. Moreover, the Flavors of meat substitutes made from plants is influenced by the extrusion process.

Fiber: The produced meat analogue's fiber and ash content were mentioned in the table 3. The high fiber level in V2 and V3 was a result of the Psyllium husk and banana stem, which also contributed to the high fiber content in the final product. Dietary fiber covers both soluble and insoluble fibres; Psyllium husk contains both soluble and insoluble fiber while banana stem fiber is primarily insoluble. Beneficial bacteria can utilise soluble dietary fiber to control blood sugar, cholesterol, and weight.

Conversely, insoluble dietary fiber stimulates the motility of the gastrointestinal tract [55, 65]. Dietary fibre improves the cohesion and texture of plant-based meat as well as the nutritional content of goods. Extrusion processing breaks down glycosidic bonds in insoluble polysaccharides, converting polysaccharides into smaller soluble components, changing the amount of dietary fiber, and making plant-based meat easier to digest and absorb [66].

Moisture: V3 had good moisture content than the other two variations. The fiber structure, texture, and flavour of plant-based meat were strongly influenced by its moisture level. Plant-based meat may be divided into two categories: high-moisture extrusion-cooked goods and low-moisture extrusion-cooked products, depending on the moisture level. While the latter has a greater moisture content and a lower shelf life, the former may be dried and kept for a longer amount of time [67]. High moisture content guarantees meat-like goods are juicy. In addition, it can produce heat of vaporization, give plasticity, lower viscosity, and function as a solvent in processes [68]. The majority of plant-based meat substitutes, such sausages and burger patties, are low in moisture.

Calcium: the calcium content in the developed plant based meat was high in variation 2 (91mg) and variation 3 (99mg). The chick peas and tapioca flour were rich in calcium content. Chickpeas are good for bone health. The Nutrients Vitamin K, calcium, and protein are all abundant in tapioca tuber. They are good for the health of bones and muscles. They can improve the flexibility, suppleness, and health of joints and limbs.

3.3 Functional properties

Table -4 : Functional properties of Banana stem, Chickpea Plant based Meat

Variations	Cooking Yield	(RW) Release water %	(CL) Cooking loss %
V1	90± 0.21	3.5± 0.41	6.1± 0.33
V2	92± 0.45	2.8± 0.45	6.8± 0.35
V3	95± 0.23	1.6± 0.31	5.2± 0.23

As indicated in Table 4, the two components of water-holding capacity (WHC) in this study are RW and CL. According to the produced counterparts' water-holding capacity, Variation 3 has the highest WHC, followed by Variations 2 and 1. This indicates that the addition of Psyllium husk powder (PHP) successfully increased the WHC of heat-induced pea protein (PP). This phenomena was previously explained well by [69], who claimed that connective tissue, meat perimysium, and myofibrillar protein (actin and myosin) all contribute to retaining the internal water in red meat, which lowers WHC. The greater WHC in evolved plant-based meat is probably due to the higher levels of Psyllium husk, chickpeas, and banana stem. Moreover, texture vegetable protein (TVP) has a lower fat content, which renders it simpler for the protein to bind to water molecules and boosts the WHC. The present results are in line with previous investigations that show that WHC improves when soy protein is used in place of meat entirely. [70]. The cooking yield is calculated using the above mentioned formula where all the three variations are measured and weighed equally and after cooking the highest weight was reported in the variation 3 followed by V2 and V1.

3.4 Morphology studies of the Banana stem, Chickpea Plant based Meat:

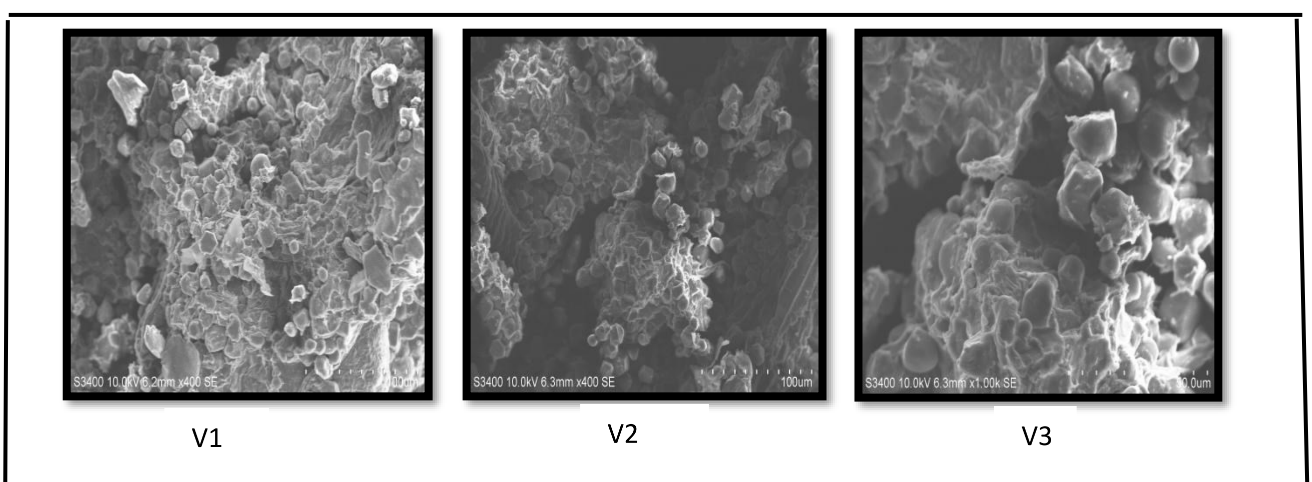


Fig .4: V1: Microscopic structure of V1 at 100x, V2: Microscopic structure of V2 at 100x, V3: Microscopic structure of V3 at 500x.

The scanning electron microscope (SEM) analysis was carried out for determining the morphological structure of plant based meat analogues at 100X magnification. The results show the irregular distribution of surface inside the analogues is due to the presence of Psyllium husk and banana stem. [71] Suggested that the formation of porous structures is due to the evaporation of water during the preparation of products. The magnifications of 100× and 500× (V3) represent the irregular globular structure. This is because protein chains significantly form the globular morphology [72]. The microstructure of meat alternatives is an important aspect in influencing their texture and sensory properties. The fiber-like structures and protein matrix provide a substantial contribution to the chewiness and mouth feel, which successfully replicate typical meat's texture. Thus, the inclusion of starch globules (Banana Stem and Chick peas) improves the product's overall palatability.

Table -5 Nutritive values comparison of developed BCPM with traditional meats.

Nutrient	Developed PBMA	Chicken (100g)	Lamb (100g)	Beef (100g)	Pork (100g)	Fish (Vanjaram) (100g)	References
Carbohydrates (g)	59	0.7	0.2-2	0	0	-	[73,74]
Energy (K.cal)	263	165	282	250	131	126	[75,76,77]
Protein (g)	16	21-23 (Breast), 19-20 (Thigh)	18	17.2	22.2	22.5	[74,75,78]
Fat	4.6	1.2	3.6	3.7	21.2	4.0	[78]
Fibre(g)	16	0	0	0	0	0	[77]
Calcium(mg)	99	15	10-13	18	7	71	[79,80]
Vitamin B12 (µg)	2.7	13-14	0.7 to 1.5	3.17	1.0	6.4	[81,82]

The nutrient composition of various protein sources differs significantly in terms of macronutrient and micronutrient concentration. This study investigates the prospective dietary roles of created BCPM (Banana stem, Chickpea Plant based Meat) in comparison to traditional animal proteins such as chicken, lamb, cattle, hog, and fish (Vanjaram) presented in Table-5.

Carbohydrates and Energy Content

The developed BCPM contains a relatively high carbohydrate content (59 g per 100 g), distinguishing it from animal proteins, which typically contain insignificant carbs. This attribute can be beneficial for any individual looking to increase their carbohydrate consumption for energy, especially athletes or those who participate in a lot of physical activity. Traditional meat sources, such as chicken, lamb, beef have few carbs, which may be beneficial for low-carb diets. The BCPM's calorie content (263 kcal) is relatively high when compared to most meats, implying that it could serve as a significant energy supply during a meal.

Protein Quality and Quantity

Protein is an essential component for muscle repair and growth, and the analysis shows that all protein sources have enough amounts. The protein level of the produced BCPM (16 g) is comparable to that of chicken (21-23 g) and other meats, making it a viable protein option.

Fat Content

The PBMA has an adequate quantity of fat (4.6 g), which is similar to lean cuts of other meats but less than that of fatty fish (21.2 g).

Micronutrients: Calcium and Vitamin B12

Particularly with plant-based diets that could otherwise lack sufficient calcium, the developed BCPM's high calcium content (99 mg) is beneficial for bone health. Traditional meats like lamb and chicken, on the other hand, contain far less calcium. Vitamin B12 is plentiful in animal products, especially fish (6.4 µg), and is necessary for blood production and brain function. Given that the developed BCPM has a lower B12 concentration (2.7 µg), consumers who want to rely on plant-based sources may consider about supplementing or fortified choices to meet their B12 needs.

3.5 Shelf-life studies through microbial analysis

Total plate count

The shelf-life studies through microbial analysis of foods and beverages can offer information on the quality of the product. BCPM product was stored in airtight containers and placed in room temperature for total study period. The total plate count was determined by analysing the generated samples. Bacteria that cause disease can be present in plant-based meat that comes from raw materials. Certain endospore-forming bacteria, such Clostridium (Cl.) spp. or Bacillus (B.) spp., could be able to survive the extrusion process, despite the fact that the majority of them would be rendered inactive by the heat [83].

The mean period in Table 6 is shown by the total plate count data. The values recorded on the first day and the last days (120th day) were 0.45 ±0.20, 0.47 ±0.20, 0.55 ± 0.20, 1.3 ±0.20, and 1.8 ±0.20, respectively.

Microbial counts were assessed by utilizing Total plate count (TPC). This investigation was showed that there was small amount growth of bacteria throughout one twenty days of storage where the product was maintained in room temperature. Spore-forming bacteria that originate from raw materials can be present in plant-based meat substitutes [84]. The overall microbial counts in their investigation ranged widely. A small number of vegetarian items had total bacterial counts of about 3 log10 CFU/g, although the majority of them only had low total bacterial counts of less than 2 log10 CFU/g. A study of vegetarian items in central Taiwan's local markets found S. aureus in 18.1% of 320 samples collected. Although the microbial loads varied, Bacillus species numbers may reach up to 4 log10 CFU/ml and B. cereus levels could reach up to 3 log10 CFU/g [85]. According to [83] Endospore-forming bacteria such as Bacillus and Clostridium species are supposed to be inactivated during the extrusion process.

Table 6: TPC content of Plant based meat

TOTAL PLATE COUNT				
0^{th} Day	**30^{th} Day**	**60^{th} day**	**90^{th} day**	**120^{th} day**
0.45±0.20	0.47±0.20	0.55±0.20	1.3±0.20	1.8±0.20

CONCLUSION

Concerns about traditional meat consumption's effects on the environment, health, and production costs have created a desire for plant-based meat substitutes. This tendency has also been aided by the growing acceptance of vegan, vegetarian, and flexitarian diets. The use of banana stem, chick peas, Psyllium husk and tapioca flour in the developed plant based meat shows good water-holding capacity, improves the texture of product. The selections of plant-based ingredients are rich in energy, protein, fat, carbohydrates, fiber and calcium contents were acceptable ranges when compared to traditional animal meat.

Due to the addition of banana stem and Psyllium husk fibers they substantially increased the overall sensory, textural and cooking properties of the developed meat analogue. The created BCPM is high in calcium and fibre compared to regular meat, and its protein level makes it a viable option for vegans. The use of dehydration and extrusion cooking has extended the shelf life of BCPM, making it a sustainable choice.

RECOMMENDATION: This research promotes a sustainable and nutritious alternative to the traditional animal based meat by using the promising technologies; extrusion and solar drying. These technologies could be used for further development of any plant based meat alternatives. Any agricultural bay products can be used to make these plant-based meat analogues, promoting product and dietary diversification for humankind.

CONTRIBUTION: M. Niharika created the research idea, proposed an experimentation strategy, and revised the manuscript before submitting it. The experiment was supervised and observed by G. Sireesha. D. Madhavi evaluated the experimental data, carried out computations, and examined relevant literature on the research subject. Bhargavi Savalapurapu provided experiment assistance and coordinated the production tests. Each author contributed equally to the manuscript's writing and bears equal responsibility for any instances of plagiarism.

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