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Formulating Meat Analogue; Health Promising Sustainable Meat Substitute

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Abstract: The increasing health concerns and environmental impacts associated with conventional meat consumption have intensified the demand for sustainable and nutritious alternatives. This study, "Formulating Meat analogue: Health-Promising Sustainable Meat Substitute", aimed to develop and evaluate a plant-based meat analogue using kidney bean, soya bean, chickpea, mushroom, and wheat gluten. Three formulations (V1, V2, and V3) were prepared with varying proportions of ingredients and assessed for sensory, physicochemical, nutritional, and microbial characteristics. Sensory evaluation by a semi-trained panel using a 5-point hedonic scale identified Variation 1 (40% kidney bean with balanced inclusion of other ingredients) as the most acceptable, with high scores for appearance, texture, and taste. Nutrient analysis revealed the product contained 23.5% protein, 18.7% carbohydrates, 3.16% fat, and provided 197.24 kcal per 100 g, alongside appreciable amounts of fiber, calcium, sodium, and iron. Physicochemical assessments confirmed favorable water and oil absorption capacities, while microbial analysis demonstrated a safe shelf life of 21 days. The findings indicate that the formulated meat analogue is a protein-rich, low-fat, and nutrient-dense product with desirable sensory properties, offering a sustainable alternative to meat. This study highlights the potential of plant-based meat substitutes to improve dietary protein intake, especially among vegetarians, while contributing to environmental sustainability

Keywords: Meat analogue, Kidney bean, Plant-based meat, Protein alternative.

I. INTRODUCTION

Humans have consumed meat since ancient times for their sustenance qualities, and it is recognised as an important source of nutrients like essential amino acids, iron, and B-Vitamins[1]. Meat and its products are nutrient-dense sources in the human diet and can fulfil most of the body's requirements because they are an important source of energy and various nutrients (macro & micro nutrients). Meat consumption plays a major role in a well-balanced diet by providing nutrients. The nutritional value of meat and meat products varies due to differences in cutting, leanness, and processing. Meat contains many nutritive and non-nutritive components, such as sodium, saturated fat, nitrites, heterocyclic aromatic amines, and polycyclic aromatic hydrocarbons, which have negative effects on human health[2]. The quality of protein is evaluated by its amino acid content; meat contains all essential amino acids, making it the best source of protein[3]. Meat analogue is the replacement of meat with other ingredients; it's also known as meat alternatives, meat substitutes, or mock meat. Due to increased consumer health awareness for a better environment and diet, demand for meat alternatives has grown. Vegetable protein consumption is increased due to animal disease, healthy food choices, and economic reasons[4]. Inefficient meat production and its global impact on food security prompted the food industry to seek sustainable alternatives to meat, which led to the development of meat analogues[5]. There are two types of meat alternatives, like cultured meat and plant-based meat analogues. The growing vegetarian population and demand for healthier diets are driving steady growth in plant-based meat analogues. The ability of various ingredients to bind with others is significant in plant-based meat analogue production to mimic the texture of meat[6]. Plant-based meat analogue is mainly formulated from sources like legumes, soya bean, wheat and lentils to mimic fibrous texture of meat by various methods including 3D printing, extrusion, 4 shear cell and soaking method[7]. An essential components of the human diet is protein and it can be derived from both animal and plant sources, animal sources are less sustainable and have negative impacts. So plant based protein are in demand because of consumer demand, stability, food affordability, food safety and nutritious. Protein malnutrition is prevalent in developed and developing countries because the direct consumption of plant-based protein is limited although they are cheaper than animal protein due to ancient practices[8]. The growing population and expanding economic leads to introduce alternative for meat products. The change in health and economic factors increases the market of plant-based meat analogues among both vegetarians and non-vegetarians. Nowadays, various meat analogue products, such as burgers and sausages, are available in the market [9]. Meat analogue is a plant based meat substitute that have quality and chemical composition of meat and have taste and smell like certain

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meat types[8]. To develop the meat analogue various methods like extrusion, protein spinning method, freeze structuring, shear cell technology, three dimensional technology are used for fiber forming process [10]. A diet with well-balanced plant sources are consider as very nutritious and helpful in human growth and development[11]. Beans are the member of Fabaceae family that includes legumes which is an important food crops as nutritionally and economically and they are cultivated worldwide. Kidney bean (Phaseolus vulgaris) is the globally important legume crops and a component of human nutrition due to their high protein content[12]. Mushroom is an essential part of human diet and mushroom based products are preferred over other plant based option for meat for their superior taste and they are environmentally friendly economically viable with high quality nutrients and sustainable alternative[13]. Kidney bean, soya bean, mushroom, wheat gluten and chickpea are the ingredients used in development of plant-based meat analogue due to their protein content and binding fibrous properties. This study aimed to formulate an optimal composition of plant-based protein reach meat analogue with various ingredients to mimic the meat like properties.

II. MATERIALS AND METHODS

A. Selection of ingredients

The nutrient rich ingredients like protein rich kidney bean and chickpea, soya bean and mushroom are added for the texture to mimic as meat, wheat gluten is added for binding property are included in the formulation of meat analogue

B. Processing of Ingredients

Kidney bean is soaked in tap water for 24 hours and grinded without adding water. Chickpea is washed in tap water and soaked for 24 hours and grinded with little amount of water to make fine paste. Soya bean is soaked in boiling water for 5 minutes and then squeezed after that grinded without adding water. Mushroom is soaked for 15 minutes in tap water and grinded without adding water to a fine texture. Wheat flour is made into dough and soaked in water for 1 hour, the dough is washed in running tap water to remove starch and the wheat gluten is formed

C. Formulation, Standardization and Preparation of meat analogue

The processed ingredients were utilised to develop three formulations, which are labelled as V1, V2 and V3. The variations are based on the proportion of ingredients to formulate 100g of product. The meat analogue is prepared by adding ground ingredients (kidney bean, chickpea, mushroom, soya bean, wheat gluten), mixing them together, making a dough, and shaping it into a sausage. The standardisation is given in Table 1. In the V1 formulation, 40 grams of kidney beans were combined with 15 grams of all the other ingredients (chickpea, mushroom, soya bean, wheat gluten). In the V2 formulation, 50 grams of kidney beans were combined with 12.5 grams of all the other ingredients (chickpea, mushroom, soya bean, wheat gluten). In the V3 formulation, 30 grams of kidney bean was combined with 17.5 grams of all the other ingredients (chickpea, mushroom, soya bean, wheat gluten). The ingredients are made into a sausage and stored in -4 degrees Celsius until used for cooking.

TABLE I STANDARDIZATION OF MEAT ANALOGUE

Ingredients	**Variation 1**	**Variation 2**	**Variation 3**
Kidney bean	40g	50g	30g
Chickpea	15g	12.5g	17.5g
Mushroom	15g	12.5g	17.5g
Soya bean	15g	12.5g	17.5g
Wheat gluten	15g	12.5g	17.5g

III. RESULTS AND DISCUSSION

Sensory evaluation is used to understand the sensory properties of foods such as appearance, color, texture, flavor, taste, which are very important in determining the acceptance of product by the consumer[14]. Analysis of variance (ANOVA) is used in evaluation of sensory attributes[15]. Sensory evaluation of formulated products was done by a panel of semi-trained members comprising students Department of Clinical Nutrition & Dietetics using five-point hedonic score. The sensory evaluation of the developed product is given in the Table II. Thus Variation 1 was selected as the best formulation, as it shows balance in terms of appearance, color, texture, flavor and taste.

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TABLE II SENSORY EVALUATION OF DEVELOPED MEAT ANALOGUE

	Appearance	**Color**	**Flavor**	**Texture**	**Taste**	**Overall acceptability**
Control	4.6±0.5	4.6±0.57	4.72±0.45	4.2±0.81	4.52±0.58	4.64±0.48
Variation 1	4.56±0.58	4.56±0.65	4.48±0.5	4.52±0.58	4.52±0.65	4.52±0.58
Variation 2	4.08±0.7	3.92±0.81	3.68±0.74	3.64±0.56	3.8±0.64	3.64±0.48
Variation 3	3.68±0.8	3.4±0.76	3.24±0.66	3.24±0.72	3.52±0.71	3.68±0.55

ANOVA results suggest that the panellists perceive meaningful differences in the texture, flavour, taste, and overall acceptability. The values as such for the appearance, $F = 11.02$, $p = .000$ (<0.05) ; color, $F = 16.37$, $p = .000$ (<0.05) ; texture, $F = 17.55$, $p = .000$(<0.05) ; flavor, $F = 32.32$, $p = .000$ (<0.05) ; taste, $F = 15.30$, $p = .000$(<0.05) ; overall acceptability, $F = 25.13$, $p = .000$(<0.05).

The physicochemical analysis was performed for the plant-based meat analogue, using BIS manual for food by using standard formulas and procedures and the results are shown in the Table III below

TABLE III PHYSICOCHEMICAL ANALYSIS OF THE MEAT ANALOGUE

S.No	Parameters	Test method	Result
1	Moisture	IS12711:1987	46.2%
2	Ash	IS12711:1987	8.14%
3	Cohesiveness	IS12711:1987	1.03
4	Gumminess	IS12711:1987	648g
5	Hardness	IS12711:1987	153N
6	Water absorption capacity	IS12711:1987	31%
7	Oil absorption capacity	IS12711:1987	2.33%

The nutrient analysis was performed for the developed meat analogue per 100g and the result were given below in the Table IV

TABLE IV NUTRIENT ANALYSIS OF THE MEAT ANALOGUE

S.No	Parameters	Test method	Result
1	Fat	IS12711:1987	3.16g
2	Protein	IS12711:1987	23.5g
3	Carbohydrate	IS12711:1987	18.7g
4	Energy	IS12711:1987	197.24kcal
5	Fiber	IS12711:1987	7.05g
6	Calcium	IS12711:1987	396mg
7	Sodium	IS12711:1987	396mg
8	Iron	IS12711:1987	1.22mg
9	Lysine	IS12711:1987	3.96mg
10	Arginine	IS12711:1987	7.53mg
11	Glutamic acid	IS12711:1987	8.17mg

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Microbial growth and shelf life is examined in the meat analogue developed, where the total microbial count in the developed meat analogue was measured as 4.0×104 CFU/g. This indicates that the plant-based meat analogue can be stored in certain conditions that limit excessive microbial growth. The microbial load of the formulated meat analogue remained within the acceptable limit for 21 days from the time of preparation, supporting the product's shelf life.

IV. CONCLUSION

The study successfully developed a meat analogue, an alternative to animal sources (meat) that helps to improve the nutritional level among people. It contains good-quality protein, serving as a sustainable alternative to meat that mimics its structural and functional properties of meat to some extent. The meat analogue is rich in protein and low in fat with moderate amount of energy that helps to maintain protein deficiency among vegetarians, people with certain disease conditions with lower side effects on consumption. The acceptable sensory qualities, microbial safety and enriched nutritional profile help people. Overall, the developed meat analogue can be a sustainable substitute for meat.

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