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# DEVELOPMENT AND QUALITY EVALUATION OF ELEPHANT FOOT YAM BASED PATTIES

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## ABSTRACT
The main objective of this study was to formulate elephant foot yam patty, which can be a sustainable alternative to the animal meat patties. Elephant foot yam and Oat flour incorporated in different proportions and its physico-chemical, and functional properties were analyzed. Patties shows reddish brown color as the yam percent increase in the formulations and there were no significant differences found in water activity and water absorption capacity. However, there was significant difference in 35% elephant foot yam formulations for pH and cooking losses (%). The higher water absorption capacity and lower cooking losses (%) was due to higher fiber and protein content. Optimum starch-protein-fiber matrix leads to fine texture and minimum drip loss during cooking. The 35% yam incorporated patties showed higher protein, optimum fiber content along with good sensory and functional properties.

**KEYWORDS:** Elephant Foot yam, Functional property, Sensory, Water absorption capacity, Patty

## INTRODUCTION
The global demand for sustainable, safe and healthy food products growing consistently, which accelerates the development of plant-based patties. Consumers are increasingly shifting towards plant-based alternatives due to concern on environmental sustainability, animal welfare, and health risk associates with consumption of red meat (Joshi & Kumar, 2015; Kyriakopoulou et al., 2019). Over a decade, various meat alternative products have been launched in the market. However, still lot of research is going on in scientific community to develop cost effective, sustainable products with minimum food additives being used, one such alternative is development of meat alternatives using underutilized plant resources.

Elephant foot yam (Amorphophallus paeoniifolius), belongs to Araceae family a tropical tuber crop cultivated in India and several southeast Asian countries. The yam is rich source of vitamin A (260 IU/g), phosphorus (34 mg/g) and calcium (50 mg/g). Apart from this it is also rich source of, protein (2.14%), fat (0.46%) and fiber (1.68%), energy, iron, zinc, manganese, potassium, flavonoids and anti-oxidants (Koni et al., 2017; Rajyalakshmi et al., 2001; Sarkar et al., 2025; Shilpi et al., 2005). Further, studies have reported that consumption of elephant foot yam associated with hypolipidemic, anti-inflammatory, hepatoprotective effects on body (Shilpi et al., 2005). Despites of its nutritional benefits utilization of elephant foot yam is only restricted to traditional culinary purpose. Development of value-added products from such underutilized vegetable crops can increase the farmers income. In recent years the tuber crops gained more attention in development of meat analogue products due to rich in starch, water-binding ability, and texture-forming characteristics (Dekkers et al., 2018). These functional properties make elephant foot yam a promising ingredient to develop meat analogues.

Among meat analogues, patties are widely accepted convince foods owing to their desirable texture and ease of preparation. The incorporation of elephant foot yam in meat analogues offers a development of nutritious, rich dietary fiber, and low fat. A lot of research is reported potato incorporated analogues, however limited research is done in elephant foot yam. Few works reported incorporation of yam along with Javanese Grasshopper, kidney beans, Lasia stem (Himashini et al., 2023; Priyatnasari et al., 2024). Compared with conventional meat, these formulations provide lower saturated fat, high fiber, bioactive compounds provide health benefits and aligns with lower red meat consumption (Fehér et al., 2020; He et al., 2020).

Despites these advantages, there are several challenges to be addressed such as replicating sensory, nutritional and textural properties to the conventional meat. Therefore, this study aims to develop a standardized meat analogue patty incorporated with elephant foot yam.

## MATERIALS AND METHODS

### Materials

Elephant foot yam, Oats, Mushroom powder, Yeast extract, Garlic powder were procured from local market. Pea protein isolate was procured from Nutrabay claiming 77% protein, Starch, Methyl cellulose and calcium chloride was procured from Venkateshwara chemicals, Huballi.

### Sample preparation

The elephant foot yam was cleaned and sliced into small pieces, then soaked in 0.5% KMS for 5 min to avoid enzymatic browning. Later yam pieces were blanched for 6-7 min in hot water and then dried in tray drier at 60°C for 7-8 hr (Mishal et al., 2022). The dried yam was pulverized and stored in air tight containers for further use. Meat analogue patties were prepared with different ratios of Elephant foot yam and Oat flour as mentioned in table 1. Other ingredients viz., Pea protein isolate, Mushroom powder, Starch, Yeast extract, Garlic powder, Methyl cellulose, Calcium chloride, Vegetable oil, Beetroot powder and Salt are remains constant in all the formulation. The dry ingredients were mixed to prepare the dough, rolled and cut into patties shape. The patties were steamed for 25 min, sealed and kept in freezer for further analysis. For analysis the freezed patties were thawed and shallow fried on hot base. Along with the meat analogue, chicken patties were prepared and considered as controlled.

**Table 1. Formulations of meat analogue**

| Sl. No. | Materials | Amount (%) | | | | |
|---|---|---|---|---|---|---|
| | | T1 | T2 | T3 | T4 | T5 |
| 1 | Elephant foot yam | 50 | 45 | 40 | 35 | 30 |
| 2 | Oat flour | 0 | 5 | 10 | 15 | 20 |
| 3 | Pea protein isolate | 10 | | | | |
| 4 | Mushroom powder | 2.25 | | | | |
| 5 | Starch | 18 | | | | |
| 6 | Yeast extract | 3.75 | | | | |
| 7 | Garlic powder | 2 | | | | |
| 8 | Methyl cellulose | 2 | | | | |
| 9 | Calcium chloride | 0.2 | | | | |
| 10 | Vegetable oil | 8.50 | | | | |
| 11 | Beetroot powder | 2 | | | | |
| 12 | Salt | 1.3 | | | | |

### Nutritional composition

### Moisture content

The moisture content of prepared meat analogue was estimated using as per the procedure described by Mishal et al., (2022). To determine the moisture content, 10g of samples were weighed and kept in Petri plates, dried in hot air oven at 110° at 4 h, kept in desiccator and weighed. The moisture content calculated according to equation 1.

$$\text{Moisture content (\%)} = \frac{\text{inital weight of Sample} - \text{final weight of Sample}}{\text{weight of sample}} \times 100 \quad (1)$$

### Ash

Total amount of inorganic mineral content was expressed as total ash and was estimated as per the procedure described by Mishal et al., (2022). A 2 g of samples was taken into the pre-weighed crucible and converted in to ash at 600°C for 5 h using muffle furnace. Ash content calculated using equation 2.

$$\text{Ash content (\%)} = \frac{\text{Weight of ash}}{\text{weight of sample}} \times 100 \quad (2)$$

### Protein

To calculate the protein content Thiex, (2009) method was followed. The 0.5g of samples were taken in digestion tube and 5g of digestion mixture was added with 10 ml of concentrated $H_2SO_4$ and digested, distillation is done followed by titration against 0.1N HCl. The % crude protein is calculated according equation 3.

$$\text{Protein (\%)} = \frac{(\text{Sample T.V} - \text{blank T.V}) \times 0.014 \times 0.1\text{Nof HCl} \times 100 \times 6.25}{\text{Weight of the sample taken}} \times 100 \quad (3)$$

### Crude fibre

Crude fibre determined by acid and alkaline hydrolysis. A 0.5g of samples was hydolysed with 1.25% acid followed by 1.25% NaOH. Hydrolyzed samples were dried and ashed in muffle furnace and Crude fibre (%) was calculated as per the equation 4.

$$\text{Crude fibre \%} = \frac{(W_1 - W_2)}{W} \times 100 \quad (4)$$

Where, $W_1$ is weight of the sample after acid and alkali wash, $W_2$ is weight of residue after ashing and W is weight of the sample

**Color, pH and Water activity (aw)**

The color of prepared meat analogue patties was measured with colorimeter (Spectrophotometer SL SH145) and expressed in terms of L*, a* and b*. The pH of the meat analogue was analyzed by digital pH meter which consist of combined glass electrode (Systronics 361). For measuring the pH, three grams of sample was added to 20 ml of distilled water to homogenize and then pH was recorded in triplicate. To measure water activity of meat analogue labSwift-aw water activity meter was used at standard working condition (25°C). Measurements were conducted in triplicates.

**Cooking loses (%) and Water Absorption Capacity (WAC)**

Cooking loss were determined with modification as described by Godschalk-Broers (Godschalk-Broers et al., 2022). Cooking loses of frozen patties were determined after thawing at room temperature. Once the sample reached room temperature patties were cooked on hot base and cooled before taking the weighing. The following equation was used (5).

$$\%\ \text{Cooking loses} = \frac{\text{Weight of patty before cooking} - \text{Weight of patty after cooking}}{\text{Weight of patty before cooking}} \text{X } 100 \qquad (5)$$

Water absorption capacity was calculated as described by Lin et al., (2002). A 25g of dried patty samples were taken and rehydrated in hot water (50°C) for 12h, the excess water was drained and WAC was recorded. The WAC was expressed as amount of water retained by per gram of dried sample by equation (6).

$$\text{WAC} = \frac{(W_b - W_a)}{W_a} \text{X} 100 \qquad (6)$$

Where, $W_a$ and $W_b$ are weights of sample before and after rehydration, respectively.

**Textural properties**

Textural properties of developed patties, such as Hardness, Springiness and Cohesiveness, was conducted at room temperature, using Texture Analyzer (Brookfield Ametek CT3 10K) fitted with TA7 Knife edge probe. Prior to texture analysis, samples were cooked and cut into one-centimeter cubes, and test was conducted at 1 mm/s pretest speed, 0.5 mm/s test speed with 2 mm target distance (Rasul et al., 2024).

**Sensory analysis**

Based on nutritional and functional properties, one best formulation was selected for sensory analysis along with the chicken patties as control. Sensory analysis was conducted by 9-point hedonic scale with 10 semi-trained panel members.

**Statistical analysis**

All the experiments were conducted in triplicate and data were expressed as mean and SD. One-way ANOVA was conducted at $P \leq 0.05$, using SPSS software (SPSS 20.0, IBM Inc., Armonk, NY, USA).

## RESULTS AND DISCUSSION

**Nutritional composition**

Moisture, Ash, Protein and fiber are play an important role in meat analogues, the variation in yam and oat has significant influence on nutritional composition as shown in Table 2. High yam incorporation increases the moisture and ash content, whereas moderate addition of oat increased protein content. The moisture content also increased as % yam increased, that is due to increase in starch composition and water binding properties of yam. Starch granules absorbs moisture and increases juiciness of the product (Kyriakopoulou et al., 2019). The moisture content reduces in reduced % yam and increased oat percentage, the fiber content in oats competes for available water during hydration and thermal processing, however statistically didn't show any significant difference at $p \leq 0.05\%$. Similarly, protein and fiber content also didn't show any significant difference at $p \leq 0.05\%$. The protein content of formulations varies from 13.96 to 14.79%, the high protein content is due to the combination of 10% pea protein and oat protein. The high protein also indicates the improved texture and juiciness of the product (Asgar et al., 2010). The Ash results were significantly different at $p \leq 0.05\%$ for 40%, 35% & 30% yam incorporated formulations. The total ash content indicates total mineral content of the product. Elephant foot yam contains good amount of potassium, calcium, phosphorus and magnesium (Singh et al., 2016).

**Table 2: Nutritional composition of Meat Analogue Patties**

| Formulations | Moisture content (%) | Protein (%) | Ash (%) | Fiber (%) |
|---|---|---|---|---|
| T1 | 52.49 ±3.81[a] | 13.96 ± 0.628 [a] | 1.13 ± 0.0315 [a] | 8.38 ± 0.390 [a] |

| | | | | |
|---|---|---|---|---|
| T2 | 56.40 ±2.32[a] | 14.51± 0.136 [a] | 1.02 ± 0.0130 [a] | 8.49 ± 0.299 [a] |
| T3 | 57.3 ± 4.58[a] | 14.55 ± 0.319 [a] | 0.74 ± 0.0541 [b] | 8.57 ±0.256 [a] |
| T4 | 53.30 ± 5.68[a] | 14.79 ± 0.368 [a] | 0.72 ± 0.0471 [b] | 8.27 ± 0.303 [a] |
| T5 | 48.93 ±2.24[a] | 14.37 ±0.437 [a] | 0.65 ± 0.0331 [b] | 8.42 ± 0.256 [a] |

*Different letters indicate significant difference at p≤0.05%

**Color**

Color is most important parameter for processed and unprocessed products as it attracts the consumer. Elephant foot yam meat analogue patties were analyzed for its color intensity L* (Light to dark), b* (blue to yellow) & a* (red to green) shown in Table 3. The color of the patties was affected as percent yam was increased in the formulations, as it was reddish brown after cooking. Only 35% yam formulation found to be significantly different (p≤0.05%), compared with other treatments. The formulated samples were compared with chicken patties and found to be having similar color expect 35% yam formulation. The variation in color intensity is may be due to starch protein interaction (Priyatnasari et al., 2024).

**Table 3: Color intensity of Meat Analogue Patties**

| Formulations | L* | a* | b* |
|---|---|---|---|
| Chicken patties | 34.50±2.49[a] | 8.25±1.30[ab] | 12.87±1.27[a] |
| T1 | 33.19±0.573[a] | 8.18±0.68[a] | 15.14±0.80[a] |
| T2 | 36.99±2.131[a] | 5.19±0.244[b] | 14.06±0.649[a] |
| T3 | 36.16±1.151[a] | 6.86±1.21[ab] | 12.2±2.522[a] |
| T4 | 41.13±1.143[b] | 7.34±0.625[ab] | 19.07±0.563[b] |
| T5 | 34.8±1.359[a] | 6.59±0.142[ab] | 13.99±1.142[a] |

*Different letters indicate significant difference at p≤0.05%

**Water activity and pH**

Water activity (aw) of analogue patties were shown in Table 4. Water activity is important in processed food products as it will indicate microbial stability. Water activity of developed patties ranged from 0.951 to 0.966, indicating the patties were high moisture food, and is prone to microbial growth (Rahman, 2020) and not significantly different (p≤0.05%). This result shows that the product needs refrigeration condition. The aw decreased in 35 & 40% of yam formulations, that can be contributed to high starch and fiber content, which enhances water binding through hydrogen bonding and capillary retention (Damodaran & Parkin, 2017). In contrast, 45% formulation showed higher water activity of 0.966, that is due to saturated water binding capacity leads to have higher unbound water.

The pH is most important quality parameter because it affects the protein functionality, water holding capacity, texture, microbial stability and shelf life of meat analogue (Damodaran & Parkin, 2017). The pH of the developed yam patties ranged from 6.35-6.54, indicates slight acidic to near neutral pH. The results revealed that increase in yam content leads to neutral acidity due to the presence of natural acidic constituents (Argaw et al., 2023). The pH of the product was slightly varied and significant different (p≤0.05%), indicates the addition of yam will alter the chemical composition and affects storage and functional properties of product.

**Table 4: Physical properties of Meat Analogue Patties**

| Formulations | Water activity | pH | Water absorption capacity | Cooking losses (%) |
|---|---|---|---|---|
| Chicken patties | 0.962 ± 0.0015[a] | 6.50 ± 0.026[b] | 0.936 ± 0.158[a] | 4.726 ± 0.287[bc] |
| T1 | 0.961 ± 0.014[a] | 6.55 ± 0.014[a] | 0.817 ± 0.531[a] | 4.401 ± 0.325[ab] |
| T2 | 0.966 ± 0.010[a] | 6.54 ± 0.021[a] | 0.831 ± 0.013[a] | 4.756 ± 0.298[a] |
| T3 | 0.951 ± 0.009[a] | 6.49 ± 0.009[b] | 1.090 ± 0.027[a] | 4.893 ±0.369[bc] |
| T4 | 0.953 ± 0.011 [a] | 6.35 ± 0.012[c] | 0.978 ± 0.031[a] | 5.740 ± 0.254[bc] |
| T5 | 0.962 ± 0.0024[a] | 6.51 ± 0.012[b] | 1.235 ± 0.133[a] | 5.350 ± 0.233[c] |

*Different letters indicate significant difference at p≤0.05%

**Water Absorption Capacity (WAC) and Cooking loses (%)**

Water absorption capacity is important functional property indicates ability to absorb and retain water within the food matrices. WAC influences texture, juiciness, cooing performance and overall product acceptability (Damodaran & Parkin, 2017). The results show numerical differences, however statistically there is no significant difference (p≤0.05%) found within the formulations. Also, exhibited good WAC due to synergetic effect of starch,

protein, and fibers are capable of binding water molecules through hydrogen bonding. Similar findings have been reported in plant-based meat systems where dietary fiber and starch rich ingredients contribute positively to water uptake and retention (Kyriakopoulou et al., 2019).

Cooking loses (%) is also a critical quality parameter as it reflects the ability of retain moisture and solids during thermal processing. The cooking loses of developed patties had significant difference ($p \leq 0.05\%$) among formulations, as Table 4 shows 35% yam incorporated patties shows highest cooking yield and 50% showed lowest.

These significant differences are due to enhanced water retention by starch and non-starch polysaccharides from ingredients, resulting higher water retention and reduced moisture loss during cooking. The similar results also reflected in water absorption capacity, when starch-protein-fiber matrix are optimum leads to fine texture and minimum drip loss (Kyriakopoulou et al., 2019). The 50% yam formulation showed lower cooking loses and WAC, that is due to low protein content in the formulation.

**Textural properties**

Texture is most important quality parameter of meat analogue as it influences consumer perception and acceptability. In present study, hardness, springiness and cohesiveness of elephant foot yam patties were evaluated and represented in fig 1. Hardness reflects the required force to compress the food samples and directly relate to firmness and bite characteristics of meat analogue products. The hardness of the patties was increased as %Yam replaced with oat flour. Increased harness is due to the presence of protein, β-glucan, and insoluble fiber causes denser product, however along with pea protein, methyl cellulose, starch, patties forms gel network, structural integrity was maintained and reduced deformation during compression. Similar results were reported by Dekkers et al., (2018), where addition of cereal fibers and proteins increased stronger gel network and results in firm texture. Springiness remains constant for all formulations indicating yam or oats doesn't have much effect on elasticity of the product after compression. Cohesiveness indicated internal bonds within the food matrix, cohesiveness of the product increased as yam flour increased that may be due to starch-protein interaction crates stronger gel formulation, however oat fiber may have interrupted the network in formulations where %oat was more (Kyriakopoulou et al., 2019).

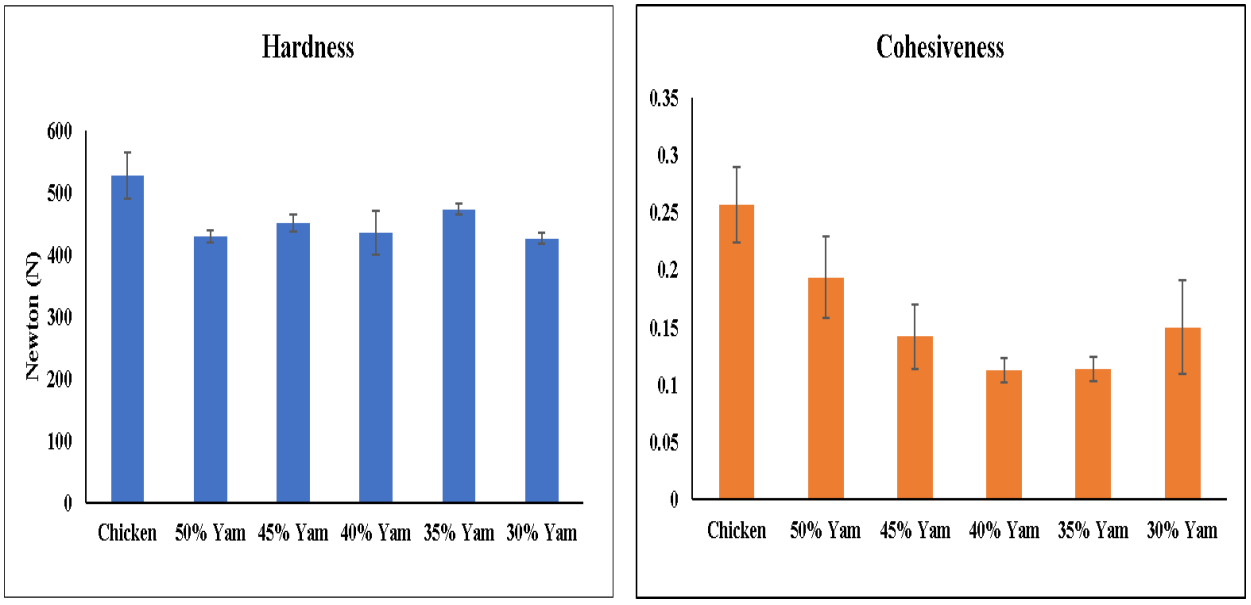



**Figure 1: Textural properties of Meat analogue patties**

**Sensory analysis**

Sensory analysis was evaluated n term of texture, flavor, color, mouth feel and overall acceptability as shown in figure 2. This analysis shows how plant-based meat analogue is closely resembles chicken patties. The nutritional and functional properties of patties were evaluated and best one was chosen for sensory analysis i.e. 35% yam incorporated patties, because consumer perception plays an important role in acceptability of any new product. Sensory analysis results show that the chicken patties scored higher than analogue patty in terms of all analyzed sensory properties, however the yam patty also showed higher scores. This score revealed that the developed patties were on par with chicken patties. The chicken patties higher scores are may due to nature fat content, complex flavor attributes, fibrous and juicy texture of chicken (Mustafa et al., 2026). Nevertheless, the yam patties also showed good textural properties with fiber-protein-starch complex, higher water holding capacity which indicates juiciness of the product. The sensory analysis scores also revered that the developed yam patties were similar to chicken patties and was acceptable.

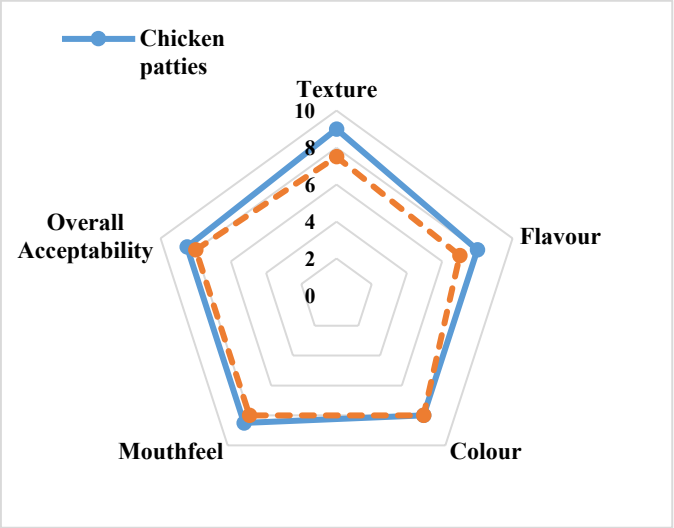



**Figure 2: Sensory analysis of Meat analogue**

## CONCLUSION

This present study demonstrated the partial replacement of yam and oat has significantly modified the textural, nutritional composition, and functional properties of the meat analogue patties. Along with that the combination of yam and oats improved cooing performance and textural properties without adverse effect on water activity, protein, moisture and fiber content. Among formulations, 35% yam and 15% oat formulation exhibited desirable nutritional, functional and textural properties. These findings proved that elephant foot yam can be used as potential ingredient for the development of sustainable high fiber, protein enriched meat analogues with acceptable quality characteristics

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### Author Contribution

Lavanya M N contributed to the plan of work, methodology, and writing, review and editing and supervision. Sankalpa K B contributed to conceptualization, methodology, writing and editing the article. Swati S M contributed to methodology, investigation, formal analysis and investigation. Sukthija contributed to methodology and editing the article. All the authors read and approved the manuscript.

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