"DEVELOPMENT AND COMPARATIVE EVALUATION OF JOWAR JAGGERY POPS AS A FUNCTIONAL SNACK ALTERNATIVE TO CARAMEL POPCORN"

PROJECT SUBMITTED

In the Partial Fulfilment of the Requirement for the Award of the Degree of

B.Sc. NUTRITION AND DIETETICS

BY

RITHIKA ANAND

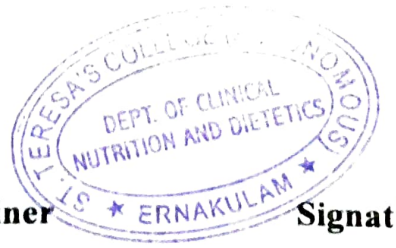
SB22ND039

DEPARTMENT OF CLINICAL NUTRITION AND DIETETICS

ST. TERESA'S COLLEGE (AUTONOMOUS), ERNAKULAM

APRIL 2025

CERTIFIED AS BONAFIDE RESERCH WORK



Signature of Internal Examiner **Signature of External Examiner**

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DECLARATION

I hereby declare that the project entitled, **"DEVELOPMENT AND COMPARATIVE EVALUATION OF JOWAR JAGGERY POPS AS A FUNCTIONAL SNACK ALTERNATIVE TO CARAMEL POPCORN"** , submitted in partial fulfilment of the requirement for the award of the degree of B.Sc. Nutrition and Dietetics is a record of original research work done by me under the supervision and guidance of **Dr. Soumya P.S**, Assistant Professor, Department of Clinical Nutrition and Dietetics, Women's Study Centre, St. Teresa's College (Autonomous), Ernakulam and has not been submitted in part or full of any other degree/diploma/fellowship or the similar titles to any candidate of any other university.

Place : Ernakulam RITHIKA ANAND

Date : 02/05/2025

CERTIFICATE

I hereby certify that the project entitled, **"DEVELOPMENT AND COMPARATIVE EVALUATION OF JOWAR JAGGERY POPS AS A FUNCTIONAL SNACK ALTERNATIVE TO CARAMEL POPCORN"** , submitted in partial fulfilment of the requirement for the award of the degree of B.Sc. Nutrition and Dietetics is a record of original work done by Rithika Anand during the period of the study under my guidance and supervision.

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ACKNOWLEDGEMENT

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ABSTRACT

The present study titled “Development and Quality Evaluation of Jowar Jaggery Pops as a Healthy Alternative to Caramel Popcorn” focused on formulating a functional snack using traditional ingredients, like jowar (sorghum) and jaggery, as a wholesome substitute for conventional caramel popcorn, typically made with corn, refined sugar, and butter. Jowar, revered as the “Great Millet,” is a nutrient-rich, climate-resilient grain increasingly recognized for its role in promoting sustainable and healthy diets. Therefore, incorporating such millets into snack formats can help bridge the gap between traditional nutrition and modern eating habits.

The experimental product, Jowar Jaggery Pops, was compared with caramel popcorn across multiple parameters, including organoleptic qualities, nutritional composition, shelf-life, consumer perception, preparation time, and ingredient cost. Sensory evaluation was conducted using a 9-point hedonic scale, with panelists rating attributes such as appearance, texture, taste, and overall acceptability. Nutritional analysis included quantification of key macronutrients (carbohydrates, proteins, fats) and micronutrients (calcium, iron, dietary fiber) using standardized AOAC methods. Shelf-life was assessed through regular monitoring of sensory characteristics under ambient storage. Cost evaluation compared the per 100g ingredient expenses of both products, while preparation time was measured to assess ease of production.

To understand consumer perception, a Check-All-That-Apply (CATA) questionnaire was used, focusing on attributes, product characteristics, emotional connection and purchase intent, which are often overlooked in conventional sensory testing. Consumer responses from the CATA analysis revealed a preference for the developed product, particularly among health-conscious individuals, emphasizing the potential for its success in the market as a functional snack alternative.Therefore, this project highlights the feasibility of using traditional, locally available ingredients to develop affordable and healthier snack options that align with modern dietary preferences. Further refinement and scaling could enable the introduction of Jowar Jaggery Pops into wider commercial channels catering to the health snack segment.

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1. INTRODUCTION

The corn crop (*Zea mays everta*) is a special variety of maize (*Zea mays*), characterized by its ability to pop when heated due to its hard pericarp and optimal internal moisture content (around 13–14%) (Ali et al., 2019). The popping quality of corn largely depends on kernel structure, moisture content, and starch composition. Caramel popcorn, a flavor variant of popped corn, is made by first popping the corn kernels and then coating them in a caramel sauce composed of sugar, butter, and sometimes corn syrup. The traditional method involves caramelization, wherein browning of sugars at high temperatures leads to the development of complex flavors and a characteristic golden color (Pratiwi et al., 2021).

Caramel popcorn is high in sugar and calories — approximately 400–500 kcal per 100g serving — and contains added fats from butter, making it an energy-dense snack low in fiber and essential micronutrients. Regular consumption of such sugar- and fat-rich snacks can contribute to obesity, dental issues, and metabolic disorders if not consumed in moderation (Malik & Hu, 2015). Popcorn, particularly flavored varieties like caramel popcorn, has gained widespread popularity as a convenient, tasty snack often associated with entertainment settings such as movie theaters (Research and Markets, 2021; PVR Cinemas, n.d.). However, despite its popularity, health concerns remain due to its high sugar and fat content.

Sorghum (*Sorghum bicolor*) is an ancient cereal grain classified under the group of crops known as millets, now popularly termed “nutricereals.” It was originally domesticated in Africa and is now widely cultivated in Asia, particularly India, and the Americas (de Morais Cardoso et al., 2017). Like other millets, sorghum is highly drought-resistant, making it ideal for cultivation in semi-arid regions (ICRISAT, 2020). Nutritionally, sorghum is rich in fiber, protein, iron, magnesium, and antioxidants, contributing to a range of health benefits. A special characteristic of sorghum is that it is naturally gluten-free, making it a suitable dietary option for individuals with celiac disease or gluten intolerance (Taylor et al., 2016). In India, jowar (the local name for sorghum) is a staple grain traditionally used in foods such as rotis and porridges. Sorghum also has a lower glycemic index compared to refined grains, and regular consumption is associated with improved

blood sugar control, digestive health, weight management, and cardiovascular benefits (Awika & Rooney, 2004).

Jowar has a unique endosperm structure composed predominantly of non-waxy starch (high in amylose) along with a significant amount of dietary fiber, resistant starch, and protein, making it highly suitable for dry heat expansion processes like popping, as done in corn Unlike corn, jowar's pericarp and aleurone layers are thicker, which contributes to its firmer texture after popping, while also enhancing its fiber content (Ratnavathi & Patil, 2013). Popped jowar offers a crunchy texture and nutty flavor, although the kernels are significantly smaller in size compared to popped corn (de Oliveira et al., 2021). From a nutritional standpoint, popped jowar retains higher levels of dietary fiber, essential minerals like iron, magnesium, and phosphorus, and powerful antioxidant compounds—especially tannins, phenolic acids, flavonoids, and 3-deoxyanthocyanidins (Stefoska-Needham et al., 2015). These antioxidants contribute to the grain's potential anti-inflammatory, cardioprotective, and antidiabetic effects.

Jowar's naturally lower lipid content and moderate energy density make it highly suitable for low-calorie snack formulations, promoting satiety without excessive caloric load (Klimis-Zacas et al., 2021). Additionally, the growing consumer interest in ancient grains, fueled by rising awareness of their health and sustainability benefits, has led to an increasing number of jowar-based innovations, including popped snacks, cereals, and energy bars . Environmentally, jowar holds an advantage over corn by requiring significantly less water for cultivation and being more resilient to drought and climate variability, positioning it as a sustainable choice for future food security (Taylor et al., 2016).

Jowar is particularly suitable for popping due to its kernel structure. Although smaller in size than corn kernels, jowar has a relatively hard outer pericarp and a dense endosperm, allowing it to expand under heat (Serna-Saldivar & Rooney, 2015). Studies show that jowar's swelling capacity is enhanced when moisture content is optimized; when dry, jowar exhibits lower swelling, whereas when slightly hydrated (around 13–14% moisture), popping efficiency improves (Taylor et al., 1997). Under dry heat conditions, jowar grains can puff and form expanded products, although the puffed size remains smaller than

popped corn. Textural studies reveal that popped jowar offers a crisp texture with slightly higher density compared to corn puffs, attributed to its greater protein and fiber content (Taylor & Dewar, 2001). Recent advances in processing techniques, such as microwave popping and hot-air fluidization, have improved the popping quality of jowar, making it a promising grain for healthy, gluten-free snack formulations (Hithamani & Srinivasan, 2014; Serna-Saldivar & Rooney, 2015).

Refined sugar, commonly used in making traditional caramel popcorn, predominantly composed of pure sucrose, is produced by chemically intensive processes that involve clarification, crystallization, and bleaching, resulting in a product devoid of micronutrients (Kaur & Gill, 2019). High intake of refined sugars is scientifically linked to increased risk of obesity, insulin resistance, type 2 diabetes, cardiovascular diseases, and dental caries (Rippe & Angelopoulos, 2016). Conversely, jaggery, a traditional unrefined, natural sweetener derived from the evaporation of sugarcane juice or palm sap, retains significant amounts of minerals such as iron, calcium, magnesium, and potassium, as well as natural phytochemicals and antioxidants like phenolic compounds (Yadav et al., 2021). While both refined sugar and jaggery are calorically dense, jaggery's superior mineral and phytochemical profile offers additional nutritional benefits (Rao et al., 2007). Moreover, due to jaggery's higher viscosity and natural stickiness compared to refined sugar syrups, lesser quantities are typically required to achieve effective coating in popped grain snacks, potentially lowering the total added sugar content while improving the binding quality. (Gosh, 2007).

Jowar (*Sorghum bicolor*), the primary grain used in Jowar Jaggery Pops, naturally possesses a low fat content, with about 3–3.5% fat, compared to corn's slightly higher fat content of approximately 4.5–5% (USDA, 2019; Taylor et al., 2016). This makes jowar, a more suitable base for formulating snacks like popcorn but with lower levels of fat. Unlike conventional caramel popcorn, which typically involves added fats like butter or oil during caramelization, popped jowar coated with jaggery requires minimal to no additional fat, resulting in a naturally lower-fat product. This composition positions Jowar Jaggery Pops as a healthier alternative, aligning with consumer trends favoring reduced-fat, functional snacks.

Considering the nutritional and functional benefits associated with jowar and jaggery, there is a strong rationale to investigate their combined application in formulating an innovative, nutritious snack alternative to caramel popcorn. This forms the basis for the present study.

NEED FOR STUDY

In the current landscape of food innovation, there has been a growing emphasis on developing healthier alternatives to traditional snacks, driven by the increasing incidence of obesity, diabetes, and lifestyle-related diseases. Traditional caramel popcorn, although popular, is rich in refined sugars and added fats, contributing to excessive calorie intake. Therefore, there is a clear need for snack products that offer similar sensory satisfaction but with improved nutritional profiles.

Ancient millets like jowar, combined with natural sweeteners like jaggery, present an opportunity to develop value-added snack products that meet contemporary consumer expectations. According to a recent report, the global healthy snacks market is projected to reach USD 152.5 billion by 2026, highlighting a strong consumer shift towards nutritious snacking options (Research and Markets, 2022). However, there is limited research focusing specifically on the sensory, nutritional, and shelf life characteristics of such millet-based popped snacks coated with jaggery. Therefore, this study aims to bridge this gap by formulating and analyzing fat-free Jowar Jaggery Pops as a healthier alternative to conventional caramel popcorn.

OBJECTIVES OF THE STUDY :

Hence, the present study entitled “Development and Comparative Evaluation of Jowar Jaggery Pops as a Functional Snack Alternative to Caramel Popcorn” was undertaken with the following objectives.

- To develop and formulate the experimental and control samples, Jowar Jaggery Pops and Caramel Popcorn, respectively for comparative analysis.
- To conduct organoleptic evaluation of sensory characteristics of the formulated products through a sensory panel.

- To analyze the nutritional composition, preparation time, cost-benefit aspects, and assess shelf-life stability based on sensory attributes.
- To assess product attributes, consumer perception and purchase intent using Check-All-That-Apply (CATA) analysis
- To popularize the Jowar Jaggery Pops recipe through a one-minute cooking demonstration video shared with the sensory panel.

2. REVIEW OF LITERATURE

The literature pertaining to the study **"Development and Comparative Evaluation of Jowar Jaggery Pops as a Functional Snack Alternative to Caramel Popcorn"** is presented under the following heads

2.1 History, cultivation and importance of Jowar (*Sorghum bicolor*)

2.2 Nutritional and health benefits of jowar and jaggery

2.3 Studies on development and evaluation of popped jowar and other popped snacks

2.4 Fat-free snack formulation and key challenges

2.5 Use of CATA (Check-All-That-Apply) for assessing consumer perception and purchase intent

2.6 Emerging trends in millet-based snacking and future scope

2.1 History, cultivation and importance of Jowar (*Sorghum bicolor*)

Jowar (Sorghum bicolor) one of the oldest cultivated cereal crops, believed to have been domesticated around 3000–4000 BCE in the northeastern quadrant of Africa, particularly in the region now known as Sudan and Ethiopia (Dicko et al., 2006), spread to India, China, and other parts of Asia, where it adapted to a wide range of agro-climatic conditions. In India, jowar is known so in place of the globally familar name "sorghum" as its scientific name suggests, and is thought to have been introduced around 1500 BCE and soon becoming an important staple for rural communities (Reddy et al., 2006). Its genetic diversity and climatic resilience made it a preferred crop among traditional farming systems, especially in arid and semi-arid regions.

As per FAO (2022), today, following wheat, rice, maize, and barley, jowar ranks fifth among the world's most important cereal crops with the major producers including India,

Nigeria, the United States, Mexico, and Sudan. In India, Maharashtra, Karnataka, Rajasthan, and Andhra Pradesh are key cultivating states. The Ministry of Agriculture and Farmers Welfare (2023), has recorded India's jowar production of approximately 4.7 million tonnes of jowar in 2022–2023, covering an area of around 4.2 million hectares. In order to increase the yield produced several techniques like improved agronomic practices, including the use of hybrid varieties, better irrigation management, and pest-resistant strains, have been employed. Despite the decline in the crop's comsumption in urban diets, it remains a critical food security crop in dryland agriculture where drought resistant crops are required for cultivation.

Jowar exhibits remarkable resilience to drought, high temperatures, and poor soil fertility, making it an ideal crop under the current context of climate change (ICRISAT, 2021). Its deep root system allows efficient water usage, while its short growing season makes it adaptable to erratic rainfall patterns. With sustainable agriculture on the rise, the crop's ability to thrive in marginal environments without heavy reliance on chemical fertilizers is of importance. According to the Directorate of Sorghum Research (now part of ICAR-Indian Institute of Millets Research), sorghum can produce reasonable yields even under 400–600 mm of annual rainfall, while most cereal crops require significantly more in order for them to even survive, making jowar crucial not only for food security but also for promoting environmental sustainability.

2.2 Nutritional and health benefits of jowar and jaggery

Jowar is a highly nutritious cereal owing to its rich profile of macronutrients and micronutrients containing about 72–75% carbohydrates, 8–12% protein, and 3–5% fat (Serna-Saldivar & Rooney, 1995). Since It is also a good source of dietary fiber, that too primarily insoluble fiber, it is benefical for gastrointestinal health. Additionally, jowar provides essential minerals such as iron, phosphorus, magnesium, and potassium (Dicko et al., 2006). Jaggery, on the other hand, a traditional unrefined sugar derived mainly from sugarcane or palm sap, retains essential minerals like calcium, potassium, magnesium, and iron, unlike refined sugar that loses microminerals during processing stages. (Rao et al., 2007). Jaggery also contains minor amounts of B-complex vitamins and antioxidants, making it a nutritionally superior alternative to crystalline white sugar.

Jowar is also notable for its high levels of bioactive components which include phytochemicals such as tannins, phenolic acids, and flavonoids, known to exhibit antioxidant, anti-inflammatory, and antimicrobial properties (Awika & Rooney, 2004). Pigmented varieties of jowar are found to have a higher concentrations of these compounds, which contribute to reduced oxidative stress leading to reduced tissue damage and potential chronic disease prevention. Jaggery also contains polyphenols and other such antioxidants especially since it undergoes very minimal processing (Sharma et al., 2009). These antioxidants assist in scavenging free radicals thereby reducing oxidative stress, and improving overall health status.

Regular inclusion of jowar in diet has been associated with various health benefits including improved glycemic control and weight management, thereby helping manage diabetes and reduce risk of cardiovascular diseases (Taylor et al., 2006). Additionally, the high fiber content helps prevent blood sugar spikes and provides insoluble fibre that supports digestive health. Sorghum-based diets have also shown positive effects in lowering cholesterol and improving satiety, both of which in combination aids weight loss. Jaggery, is of immense traditional value in Ayurvedic medicine, and is believed to aid digestion, detoxify the liver, and act as a respiratory tract cleanser thus helping in overall detoxification of the human body(Chandran et al., 2017). Jaggery provides quick bouts of energy and is often recommended in traditional diets for boosting iron levels to combat anemia, as it is a rich plant source of iron.

2.3 Studies on development and evaluation of popped jowar and other popped snacks

The thermal process wherein upon heating, moisture inside the grain rapidly vaporizes , causing the grain to expand and “pop”, is referred to as ‘Popping’ Traditionally, Jowar is popped using dry heat methods that include sand roasting or hot air popping (Sakhare et al., 2014). The moisture content of jowar prior to popping plays a critical role, with an optimal range of around 13–14% is minimum required for better expansion and puffing (Serna-Saldivar & Rooney, 1995). Food processing techniques such as microwave popping and fluidized bed roasting are modern alternatives that have been explored for more uniform popping and uniform yield industrial-scale production of popped sorghum (Alpaslan & Hayta, 2006).

Similarly, other grains like maize, that is, corn, popularly used in the making of popcorn, have been extensively studied, where size of the kernel, thickness of the pericarp and internal moisture levels impact expansion volume and thereby the popping efficiency.

The texture of popped jowar products will be crucial for consumer acceptance since organoleptic attributes such as crispness, lightness, and mouthfeel are key sensory characteristics that are noted and evaluated in popped grains (Mishra et al., 2014). Studies show that higher popping expansion ratios have a positive correlation with consumer preference for crunchiness and appearance (Sandhu et al., 2007). Sensory evaluation typically includes hedonic scaling for parameters like color, flavor, texture, and overall acceptability all of which are relevant in popped snack products (Kaur et al., 2018). For jaggery-coated popped products, balancing sweetness and maintaining a non-sticky, appealing texture as well, will become an additional requirement for consumer liking .

Textural properties like crispness, color stability, and sensory attributes are monitored over time to determine shelf life of popped snacks. However, popped products are sensitive to moisture uptake, leading to sogginess and thereby, reduced acceptability. Common methods of shelf-life evaluation include regular sensory panels consistently assessing such organoleptic properties combined with instrumental texture analysis, crucial to changes during storage (Mariotti et al., 2006). Packaging solutions like moisture-barrier materials are often employed to prolong the crispness, prevent sogginess and maintain quality during shelf life assessments.

2.4 Fat-free snack formulation and key challenges

Fats usually provide a specific texture, flavor, and mouthfeel that is desirable, which ideally, must also be found in fat-free snacks that must mimic these characteristics,thus requiring strategic formaulation techniques .Therefore, various methods such as hot air puffing, extrusion, and popping are employed in the making of low-fat or fat-free snack products in order to bring down fat levels, since they ensure expansion and crispness without the need for frying in oil. (Guha & Ali, 2004). Besides, natural puffing techniques, such as dry heat popping, helps maintain the integrity of nutritional components without compromising on the desirable crunchy texture required.

Natural sweeteners, like jaggery, are now increasingly used in snack formulations to enhance flavor, in efforts to avoid the excess consumption of refined sugar. Besides imparting its characteristic taste, jaggery also contributes minerals like iron, magnesium, and potassium, giving rise to more nutritious snacks (Rao et al., 2007). Unlike refined sugars, jaggery undergoes very minimal processing, owing to which it retains several beneficial phytochemicals, thus making it a preferred choice for health-focused snack formulations.

Since fat is crucial for flavor development, moisture retention, and mouthfeel in conventional snacks, in its absence, manufacturers face challenges in maintaining product acceptability and in building purchase intent among consumers. This is also because, fat-free products can turn out to be too dry, hard, or bland if not properly formulated, due to which consumers do not make positive correlations despite the health benefits offered. Therefore, techniques like moisture control, optimal puffing conditions, and inclusion of flavor enhancers (natural or permitted additives) become critical to ensure consumer acceptability (Mehta & Sharma, 2017) in order to preserve the fat-free aspect of the snack peoduct. Additionally, achieving shelf stability without fats ,which usually act as barriers against moisture , reduces moisture control, increasing risk of contamination, therefore requiring innovative packaging and storage solutions.

2.5 Use of CATA (Check-All-That-Apply) analysis for assessing product attributes and purchase intent

The Check-All-That-Apply (CATA) technique is a consumer-friendly method that is applied to assess consumer perception towards product attributes, as it allows participants to select all terms or descriptors they feel applicable to a product, from a provided list. Unlike scaling methods, involving a score, CATA avoids the complexity of scoring or ranking, instead recording consumer perceptions in a straightforward manner (Ares et al., 2010). It provides qualitative and even semi-quantitative data that can be statistically analyzed to generate sensory profiles and perceptual maps, that help product manufacturers understand how their product can be potentially positioned in the market. In the CATA method, consumers respond to lists covering aspects such as sensory attributes such as organolpetic parameters, emotional associations, nutritional perceptions, and other relevant

such as organolpetic parameters, emotional associations, nutritional perceptions, and other relevant product characteristics (Jaeger et al., 2013). Thus, this approach has the ability to capture spontaneous, natural reactions without forcing participants into rigid scoring scales, making it ideal for evaluating novel. or unfamiliar food products.

CATA has gained popularity in the domain of sensory evaluation as a supplementary element, due to its simplicity and reliability as it allows researchers to understand how consumers perceive various sensory characteristics such as texture, flavor, aroma, and appearance, which are crucial components in building a positive product image(Ares & Varela, 2014). In recent food product development studies, CATA has been employed to compare products on multiple attributes simultaneously, making it easier to identify sensory drivers of liking and product differentiation, which helps product manufacturers in making changes to exisiting products or even introducing a new array of similar products. (Varela & Ares, 2012).

In the field of new food product development, particularly for health-oriented snacks, analysis of consumer perception is critical for market acceptance. CATA serves as an easy, rapid yet powerful tool for obtaining consumer-driven insights that guide product optimization, marketing strategies, and brand positioning within the market where other similar products compete. (Ares et al., 2010). The data obtained can help developers understand whether features like ‘high fiber’, ‘low calorie,’ or ‘unique flavor profile’ resonate with the target audience, thus helping build competitive advantages. Moreover, by incorporating emotions and purchase intent, CATA extends beyond basic sensory evaluation to offer a complete picture of consumer response, enabling efficient product launches and innovations, also projecting the brand as one that prioritises customer health and satisfaction. (Dooley et al., 2010).

2.6 Emerging trends in millet-based snacking and future scope

In recent years, millets have made an exceptional comeback with renewed global interest in millets, driven by their exceptional nutritional profile, climate resilience, and sustainability advantages benefiting both cultivators and the environment. Millets like jowar, especially owing to its gluten-free nature are increasingly recognized as ideal

ingredients for health-conscious snacking, addressing the rising demand for high-fiber, gluten-free, and low-glycemic index foods especially for celiac disease and diabetes patients(Anitha et al., 2021).

Despite Africa being home to extensive millet cultivation, particularly in countries like Nigeria and Niger, India stands out as the largest single-country producer of millets globally, contributing approximately 41% of the world's total millet output, with high export potential due to growing demand for millets to be included in diets.(FAO, 2023; Ministry of Agriculture & Farmers Welfare, 2023).

In India, the term "Millets" was officially rebranded as "Nutricereals" - a term coined to highlight the superior nutritional quality of millets compared to staple cereals like rice and wheat (Muthamilarasan & Prasad, 2015). Owing to health, nutrition, and sustainability trends, global interest in millet-based foods has risen rapidly (Saleh et al., 2013). In recognition of the importance of millets in the aspects of nutrition, agronomy and economy in the present world, the Government of India proposed the idea of celebrating 2023 as the "International Year of Millets". This proposal was subsequently endorsed by the Food and Agriculture Organization (FAO) and the United Nations General Assembly (UNGA) (FAO, 2023; United Nations, 2021), following which various activities were organized to raise awareness about the benefits of millets, including international conferences, exhibitions, millet based competitions, walkathons to raise awareness, buyer-seller meets, food festivals, and policy dialogues.

India, being the lead promoter, took initiative and hosted large-scale campaigns such as the Global Millets (Shree Anna) Conference, launched promotional events in partnership with food companies in the private sector, and introduced millet-based recipes in public food programs (FAO, 2023; Ministry of Agriculture & Farmers Welfare, 2023) while also collaborating with FSSAI to organize the "Eat Right Millet Melas" where interactional educational activities to raise awareness on millet consumption, culinary demonstrations, millet baseed food exhibitions etc. were carried out (FSSAI, 2023) Collaborations with international bodies like the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) facilitated research dissemination and farmer outreach activities focused on millet cultivation and value addition of millet based food products to promote

sustainable agriculture, food security, and nutrition, especially in the context of climate change and shifting dietary patterns (ICRISAT, 2023).

Millet-based snack innovations are focused on creating value-added products that are even more nutritionally superior than they are as such, besides being tasty and convenient for consumption. Processing tehcniques applied in order to enhance sensory appeal and prolong shelf life, include puffing, popping, extrusion, and baking (Devi et al., 2014). Experimenting with fortifying millet snacks with additional nutrients, incorporating natural sweeteners , and diversifying flavor profiles to cater to modern palates, are also being carried out and tested for product acceptability (Saleh et al., 2013). Furthermore, the "clean-label movement", which emphasizes on minimal processing and natural ingredients, has encouraged the production of millet-based snack options free from artificial additives, Class II preservatives and food colours, aligning with the preferences of health-conscious consumers. Millet snacks have thus evolved from traditional whole grain forms into versatile,ready-to-eat snack products suitable for global markets.

Although the field of millet-based snack development is promising, several research avenues remain unexplored. Future studies are required to optimize processing techniques that prevent loss of bioactive compounds while enhancing sensory characteristics. Research should also focus on the development of composite snacks combining millets with other nutritional components found in legumes, seeds, and functional ingredients to create nutritionally balanced snack options (Saleh et al., 2013). Additionally, consumer behavior studies investigating taste preferences, acceptance levels, and willingness to pay for millet-based snacks can guide better product positioning for which awareness on millet consumption and associated benefits, is essential and must be imparted. Expanding clinical research on the health benefits of regular millet consumption, such as its role in managing diabetes, obesity, and cardiovascular diseases, will further strengthen the case for integrating millets into daily diets through innovative snack formats and motivate individulas to switch to healthier snack options with minimal processing. Finally, sustainable sourcing, supply chain improvements, and packaging innovations also offer promising directions for future exploration in the field of millet cultivation, utilization and consumption.

3. METHODOLOGY

The present study entitled 'Development and Comparative Evaluation of Jowar Jaggery Pops as a Functional Snack Alternative to Caramel Popcorn' was conducted and the methodology adopted is discussed under following headings.

3.1 Selection of Raw Materials

3.2 Development of Experimental Sample (Jowar Jaggery Pops) and Control Sample (Caramel Popcorn)

3.3 Organoleptic Evaluation

3.4 Nutrient Analysis

3.5 Shelf-life Analysis

3.6 Evaluation of Preparation Time

3.7 Cost Analysis

3.8 Statistical Analysis

3.9 CATA Analysis for Consumer Perception, Product Attribute and Purchase Intent Evaluation

3.10 Promotion and Awareness Creation for the Developed Product

3.1 Selection of Raw Materials

The raw materials required for the preparation of the experimental sample (Jowar Jaggery Pops) and the control sample (Caramel Popcorn) were procured from local and online commercial retail outlets.

3.1.1 *Experimental Sample (Jowar Jaggery Pops):*

Whole jowar (Sorghum bicolor) grains and standard jaggery blocks were sourced from a supermarket in Kerala. The jaggery used was a traditional variety commonly available for

3.1.2 *Control Sample (Caramel Popcorn):*

Popcorn kernels, refined sugar, and single-use butter portions were obtained from a grocery store.

All ingredients were commercially available and selected for their suitability in snack preparation and sensory evaluation.

Plate 1: *Raw ingredients for Experimental Sample (Jowar Jaggery Pops)*

Plate 2: *Raw ingredients for Control Sample (Caramel Popcorn)*

3.2 Development of Experimental Sample (Jowar Jaggery Pops) and Control Sample (Caramel Popcorn)

The experimental sample, Jowar Jaggery Pops, was developed using a standardized recipe formulated for this study, while the control sample, Caramel Popcorn, was prepared following conventional methods. Both were prepared under similar conditions to enable comparative sensory and nutritional evaluation.

3.2.1 *Development of Jowar Jaggery Pops (Experimental Sample)*

Ingredients

- Whole jowar grains – 100 g
- Jaggery – approximately 45 g (adjust to taste)

Preparation Method

- Rinse the jowar grains by filling a vessel with water, covering the grains fully.
- Heat the water (do not bring to boil), strain, and discard any floating/misshapen grains.
- Repeat rinsing until the water runs clear.
- Soak the rinsed grains in water for 5 minutes.
- Strain and spread them on a clean cloth to dry.
- Dry for 2 to 3 hours, until grains are moisture-free.
- Heat a clean, dry pan on medium-high flame; add batches of dried jowar grains.
- Stir grains until popping begins; immediately cover with a transparent lid.
- No visible fat (oil or butter) was used during the popping process; only dry heat was utilized.
- Repeat for remaining batches.
- Melt 45 g jaggery over low heat to form a syrup (ensure it is not too watery).
- Add popped jowar grains to melted jaggery and toss until grains are evenly coated

Note:

Proper cleaning, soaking, and drying were essential. During standardization trials, omission of soaking and drying led to reduced popping quality and a harder texture. Use of only dry heat without any added fat ensured a lighter, fat-free final product.

3.2.1 *Development of Traditional Caramel Popcorn (Control Sample)*

Ingredients

- Corn kernels – 100 g

- Refined sugar – 45 g (standardized amount)
- Butter – 10–15 g (for sautéing)

Preparation:

- The selected popcorn kernels were heated along with butter in a deep pan over medium-high flame, ensuring even distribution of fat across the kernels.
- Once the kernels began popping, they were continuously stirred and monitored to avoid burning.
- Separately, a caramel syrup was prepared by heating the standardized quantity of refined sugar (~45 g) until it melted and reached a golden brown consistency.
- The freshly popped popcorn was then coated evenly with the prepared caramel syrup.
- After coating, the caramel popcorn was spread onto a clean surface to cool and set properly.

Plate 3 : *Final products developed*

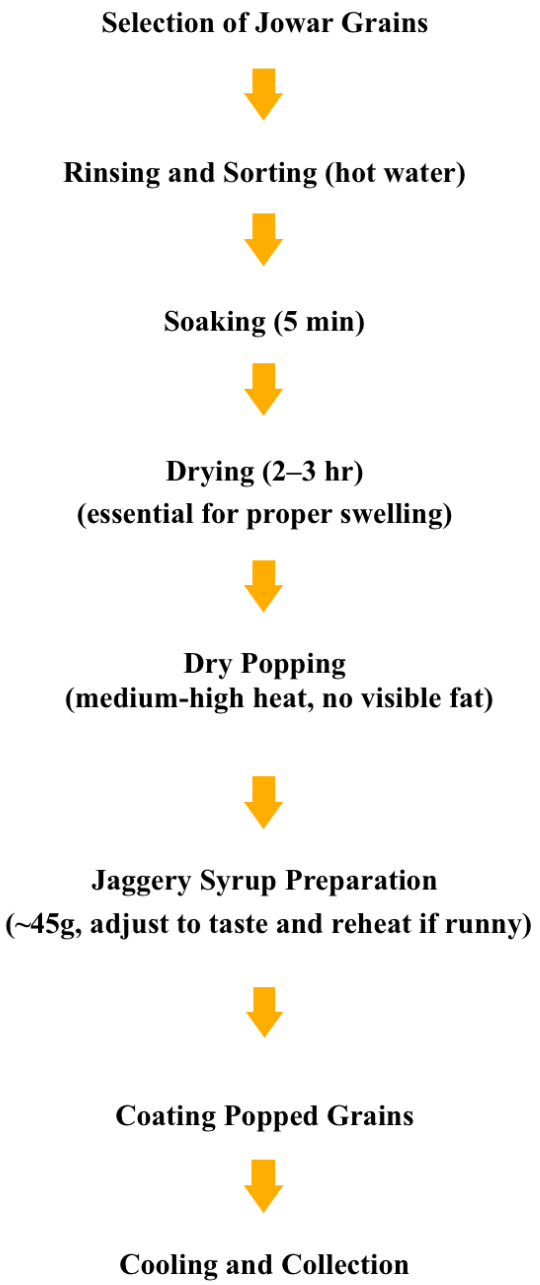

Fig. 1 : Preparation of Jowar Jaggery Pops

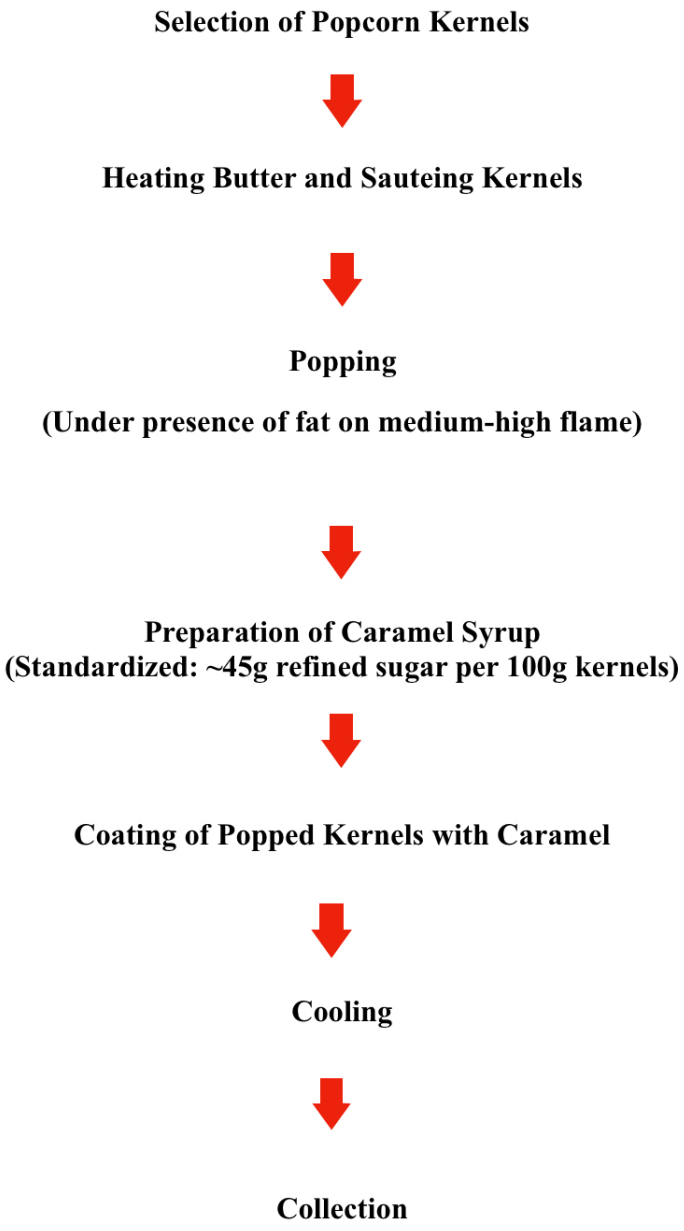

Fig. 2: Preparation of Caramel Popcorn

3.3 Organoleptic Evaluation

Organoleptic evaluation was employed to assess the food products based on sensory attributes such a appearance, taste, texture, and overall acceptability.A nine-point hedonic scale was used, to comparatively score both the products based on these attributes where 1 indicated “dislike extremely” and 9 indicated “like extremely,” to capture the extent of likeness and preference for each of them.

3.3.1 *Sensory Scorecard*

A scorecard was prepared to facilitate sensory evaluation and evaluate the appearance, taste, texture, and overall acceptability of the samples using the standardized nine-point hedonic scale.

‘Sensory Evaluation Card’ is attached as Appendix I.

3.3.2 *Selection of judging panel*

A group of ten untrained panelists was selected, who were briefed about the evaluation method to carry out the organoleptic evaluation, criteria for scoring and the reference 9-point hedonic scale and instructed to rate the sensory attributes (appearance, taste, texture, and overall acceptability) of both the experiment and control samples.

Fig 3 : Members of the panel evaluating

3.4 Nutrient Analysis

The experimental and control samples were outsourced to the College of Agriculture, Vellayani, Thiruvananthapuram, where they were subjected to proximate nutrient

analyses of selected macronutrients and micronutrients of relevance to the study. These parameters evaluated included the following :

PARAMETERS	UNIT	METHOD ADOPTED
Energy	kcal/100g	AOAC 20th Edition, 2016; Atwater General Factors
Carbohydrate	%	AOAC 20th edition 2016: 986:25
Protein	g/100g	AOAC 20th edition 2016:920:87
Fat	g/100g	AOAC 20th Edition, 2016: 963.15
Dietary Fibre	g/100g	IS 11062 - 1984, R-2015
Iron	ppm	AOAC 20th Edition, 2016: 944.02
Calcium	%	AOAC 20th Edition, 2016: 984.27
Moisture	%	AOAC 20th Edition, 2016; 925.10

Table 1 : Methods adopted for Analysis of Nutrient Composition

3.5 Shelf-life Analysis

Shelf-life analysis was conducted at baseline (Day 1) and after 30 days of storage and closely monitored in between, at ambient conditions. No instrumental or microbiological analysis was performed and the assessments were limited to sensory and visual evaluation where observations were made with respect to appearance, aroma, and texture to assess any notable changes over the storage period.

3.6 Evaluation of Preparation Time

The preparation time for both experimental and control samples was qualitatively assessed based on the duration and complexity of standard preparation. The time taken to prepare 100g of each product was recorded to evaluate the ease of preparation. This included both preliminary steps and cooking time. These observations were used to compare the practical feasibility of preparing each product under typical domestic conditions.

3.7 Cost Analysis

The cost of production was calculated by estimating the cost of raw materials used in preparing 100g of both experimental and control samples. Ingredient costs were based on prevailing local market prices in Kerala at the time of procurement. The total cost per 100g was obtained by summing the individual component costs. No fixed overheads, equipment depreciation, or labor charges were included, as the analysis was conducted on a domestic scale. These values are specific to this study and may vary depending on factors such as brand, store, sourcing location, or seasonal price fluctuations.

3.8 Statistical Analysis

The sensory evaluation scores collected for overall acceptability were collected using a 9 point hedonic scale, producing ordinal data. As the data were derived from a small panel size (n = 10), making it inappropriate to assume a normal distribution,the Mann–Whitney U test, a non-parametric statistical method , was employed to compare the median scores between the experimental (Jowar Jaggery Pops) and control (Caramel Popcorn) samples. This test is used to compare whether two independent samples differ in their average rankings when the data are not normally distributed.

3.9 CATA Analysis for Consumer Perception, Product Attribute and Purchase Intent Evaluation

A Check-All-That-Apply (CATA) questionnaire was used to evaluate perceptions of the two samples—Jowar Jaggery Pops (experimental) and Caramel Popcorn (control). The CATA analysis form included four dimensions: Nutritional Benefits, Product Characteristics, Emotional Connection, and Purchase Intent. Panelists (n = 10) selected all attributes they associated with each product based on their knowledge, preferences, and perceived judgements. . Purchase intent was rated on a 5-point Likert scale (1 = Not likely at all, 5 = Very likely).

Although nutritional attributes were included, they were not emphasized in the analysis, as such benefits are often overrepresented in surveys due to perceived desirability rather than actual consumer motivation. Instead, the analysis focused on product characteristics

and emotional associations, which more accurately reflect real-world drivers of preference. The most frequently selected attributes for each sample were identified and visually compared to interpret overall levels of consumer perception.

'Check-All-That-Apply (CATA) Analysis' questionnaire is attached as Appendix II.

3.10 Promotion and Awareness Creation for the Developed Product

To create awareness and promote the developed product, Jowar Jaggery Pops, and familiarize panel members with its preparation, a 1-minute cooking demonstration video was used as an audio-visual aid in conjunction with the sensory evaluation.The video highlighted the preparation steps, key ingredients, and health-focused aspects of the product, serving as an informal promotional tool aimed at increasing familiarity and was shown to sensory panel members prior to evaluation to enhance understanding of the product's ingredients, preparation process and health-oriented appeal.

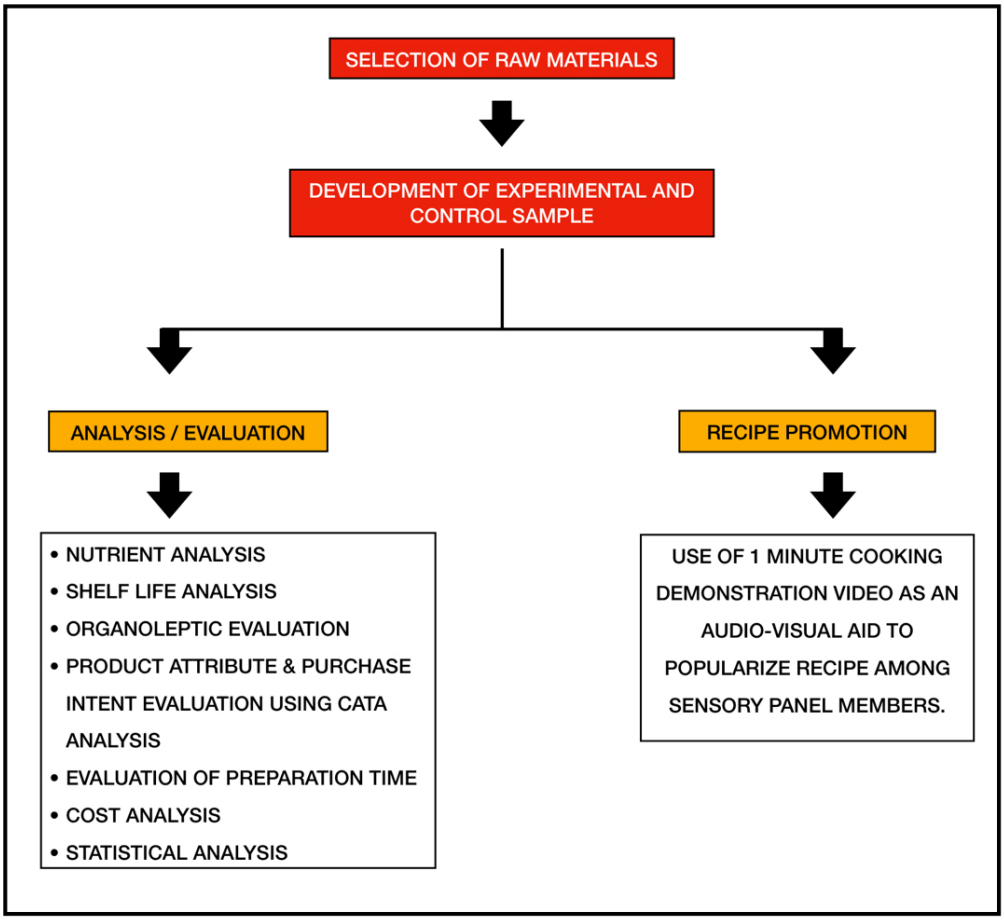

Fig 4 : Research Design

4. RESULTS AND DISCUSSION

The results and discussion for the present study entitled 'Development and Comparative Evaluation of Jowar Jaggery Pops as a Functional Snack Alternative to Caramel Popcorn' is discussed under the following topics:

4.1 Organoleptic Evaluation of Jowar Jaggery Pops and Caramel Popcorn

4.2 Nutrient Analysis of Experimental and Control samples per 100g

4.3 Comparison of Shelf-life stability

4.4 Total time taken for preparation

4.5 Incurred costs

4.6 Interpretations made from Statistical analysis

4.7 Product Attribute associations with Consumer Perception and Purchase Intent likelihood based on CATA Analysis

4.1 Organoleptic Evaluation of Jowar Jaggery Pops and Caramel Popcorn

A 9-point hedonic scale was used to evaluate the sensory attributes of the experimental sample 'E' (Jowar Jaggery Pops) and the control 'C' (Caramel Popcorn). Ten semi-trained panelists rated both products based on four parameters: appearance, texture, taste, and overall acceptability—each scored out of 9. For each parameter, the maximum possible score was 9 per panelist. The mean scores for each organoleptic parameter, total organoleptic score (out of 360), acceptability percentage, mean and rank were calculated and are presented in Table 4.1.

Similar to findings by Xu, N. et al. (2023) in puffed corn flake optimization, the Jowar Jaggery Pops sample demonstrated favorable organoleptic attributes such as crispness and overall acceptability, which are critical for consumer appeal in puffed snack products.

Sample	Appearance (9)	Texture (9)	Taste (9)	OAA (9)	Total Score (360)	Acceptability (%)	Rank
Jowar Jaggery Pops (E)	8.2	8.2	8.7	8.5	336	93.33%	1
Caramel Popcorn (C)	7.6	6.9	7.4	7.2	291	80.83%	2

Table 2 : Mean score of organoleptic parameters, Total Organoleptic score, Acceptability and Rank

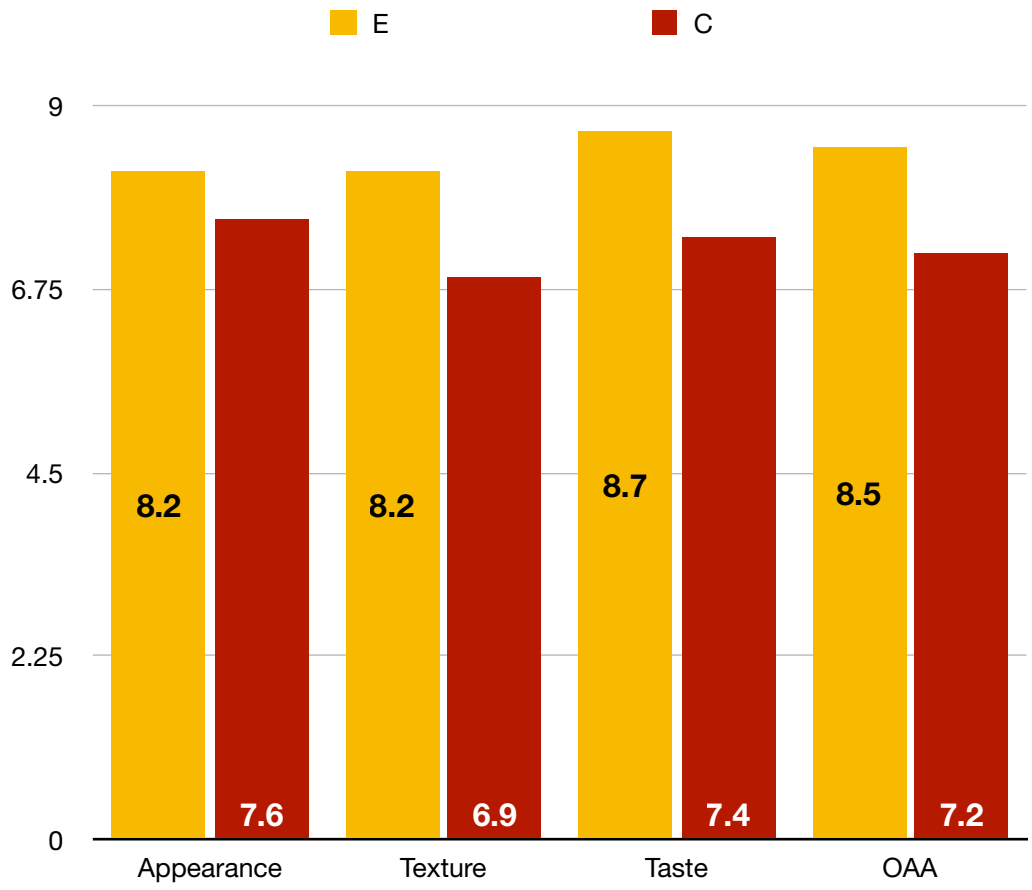

Fig 5 : Mean Score of Sensory Evaluation

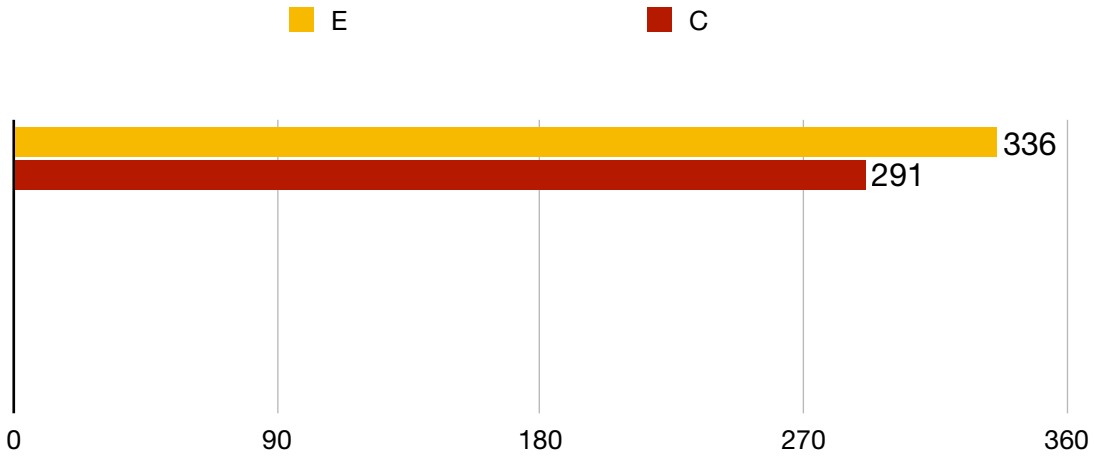

Fig 6: Total Organoleptic Score

The experimental product, Jowar Jaggery Pops, was preferred over the control, Caramel Popcorn, in all sensory parameters—appearance, texture, taste, and overall acceptability. and flavor, contributing to the higher acceptability of the experimental product. According to Joshi and Raghavendra, et al. (2021), in the development and optimization of sorghum-based nutribars, the incorporation of jaggery not only enhances the nutritional profile but also improves the sensory acceptability of the bars, making them appealing as traditional snack alternatives.

The use of equal amounts of jaggery and sugar in both recipes, resulted in a richer, more uniform coating on the Jowar Pops but an insufficient, uneven coating on the popcorn. This affected not only the visual appeal but also the texture and flavor, contributing to the higher acceptability of the experimental product (93.33%).The coating of jaggery as seen in jaggery-coated flaked and puffed rice products developed in other studies (Krishan Kumar, et al) showed improved sensory acceptability and enhanced nutritional quality to the experimental sample.

4.2 Nutrient Analysis of Experimental and Control samples per 100g

Proximate laboratory analysis revealed that Jowar Jaggery Pops (E) had a slightly lower energy value (368.5 kcal/100g) compared to Caramel Popcorn (C) (372 kcal/100g), suggesting a marginally lighter caloric profile. The experimental sample also exhibited higher protein (12.1 g vs. 11.2 g), dietary fiber (13.5 g vs. 12.8 g), and iron content (22.5 ppm vs. 17.5 ppm), indicating improved nutritional density, particularly in micronutrients

PARAMETER	UNIT (per 100g)	JOWAR JAGGERY POPS (E)	CARAMEL POPCORN (C)
ENERGY	kcal	368.5	372
CARBOHYDRATE	g	70.8	71
PROTEIN	g	12.1	11.2
FAT	g	4.1	4.8
IRON	ppm	22.5	17.5
CALCIUM	%	0.6	0.5
MOISTURE	%	18.5	20
DIETARY FIBRE	g	13.5	12.8

Table 3 : Nutrient Composition of Selected Parameters

and fiber. Jowar Jaggery Pops contained slightly less fat (4.1 g/100g) compared to Caramel Popcorn (4.8 g/100g), reflecting its leaner preparation method without butter or caramel syrup. Calcium content was marginally higher in the experimental sample (0.6% vs. 0.5%), while moisture levels were slightly lower (18.5% vs. 20%), which may contribute positively to the shelf stability of the Jowar-based snack. Overall, the experimental product demonstrated favorable nutritional attributes, especially for health-conscious consumers seeking a higher-fiber, higher-protein alternative with functional benefits.

In support of this study's nutritional profiling of Jowar Jaggery Pops, previous research has highlighted the nutritional retention and proximate values of popped sorghum. Dhadke et al. (2022) analyzed two sorghum varieties post-popping, Parbhani Jyoti and Maldandi, and reported notable nutrient content, including 8.2% moisture showing that excess moisture in sample C may be that from jaggery, around 10.4% protein, and over 71% carbohydrates, confirming that popping retains essential nutrients. In comparison, Olayinka and Akinwande (2016) examined caramel-flavored popcorn and found crude fat between 3.8–4.6%, protein ranging from 8.1–10.5%, and starch contents of 61.0–67.9%, thus providing a relevant benchmark for evaluating and comparing the proximate composition of Jowar Jaggery Pops with conventional caramel popcorn.

4.3 Comparison of Shelf-life stability

After 30 days of storage, Caramel Popcorn (control) exhibited mild deterioration in sensory quality. A faint pungent aroma developed, resembling stale or scorched sugar, alongside a noticeable softening of texture, indicating potential moisture absorption. These changes are likely linked to uneven or insufficient caramel coating, which may have compromised the product's ability for moisture control and preservation.

In contrast, Jowar Jaggery Pops (experimental) retained a firmer texture and exhibited only a mild intensification of jaggery aroma. The sample was deemed fit for consumption based on sensory attributes like aroma and texture till around Day 7 and it was observed that there was no alterations in mouthfeel and taste. The even jaggery coating may have served as a better barrier to moisture, contributing to improved shelf life stability. The natural preservative properties of jaggery, along with its traditional use in shelf-stable foods, may have contributed to the extended sensory quality and perceived freshness of the experimental sample.

Various studies have explored the shelf-life stability of sorghum-based and extruded snack products under differing storage and packaging conditions. Sahu et al. (2018) found that MPET packaging extended sorghum extrudate shelf-life to 35 days, while HDPE and LDPE provided shorter durations. Unhale et al. (2012) reported up to 18 days of stability in sorghum roti with potassium sorbate and ascorbic acid treatment. ICAR (2019) observed that metallized polyester helped preserve sorghum cookies' texture and sensory quality over 120 days. Similarly, Mane Kancor's study on caramel popcorn highlighted the effectiveness of natural antioxidants like rosemary extract in delaying oxidative rancidity. Compared to these, the current study's products showed perceptible changes in freshness, texture, and aroma within approximately 10-14 days.

No visible microbial growth or spoilage was observed on either product. However, the absence of microbial (e.g., Total Plate Count) analysis limits definitive conclusions.

4.4 Total time taken for preparation

SAMPLE	AMOUNT (in g)	TIME TAKEN		
		Preliminary steps (in hours/days)	**Cooking (in min/hours)**	**Total time taken**
Jowar Jaggery Pops (E)	100	Soaking and drying (2 to 3 hours)	Popping (Soaked grains : < 3 min ; Unsoaked grains : >3 min) + Melting and mixing in jaggery : 3 min	Soaked = 3 hours and approx. 5 min & Unsoaked = 5-8 min
Caramel Popcorn (C)	100	No preliminary techniques carried out	Saueting and Popping : <5 min Caramel making and coating : 10 min	15 minutes

Table 4 : Preparation time for E and C

The preparation times for both the experimental (Jowar Jaggery Pops) and control (Caramel Popcorn) products were recorded and compared to assess practical feasibility. For the experimental sample, Jowar grains underwent a preliminary preparation stage involving soaking and drying, for cleaning and increasing swelling property, which required approximately 2–3 hours. Cooking involved popping the grains (under 3 minutes for soaked and over 3 minutes for unsoaked grains), followed by melting and mixing jaggery (approximately 3 minutes), resulting in a total time of about 3 hours and 5 minutes for soaked grains.

In contrast, Caramel Popcorn did not involve any preparatory procedures. Its cooking process included sautéing, popping (<5 minutes), and caramel preparation and coating (around 10 minutes), with a total preparation time of approximately 15 minutes. While Jowar Jaggery Pops may offer a healthier profile, the extended preparation time could pose a barrier to frequent or large-scale production unless pre-processing strategies are optimized.

In comparison to studies involving soaking for 2 min and subsequent conditioning for 3 hours (Kakade et al. 2020) or using a 30-minute soak, 12-hour conditioning, at lower popping temperature (Gosavi et al. 2022) for high popping yield and good crispness, the current study adopted a simplified approach with soaking for only 2 hours or even without soaking, focusing on practicality and time efficiency in home-style preparation.

4.5 Incurred costs

The cost of producing 100 grams of each sample was calculated based on the quantity and market price of individual ingredients. For the experimental product, Jowar Jaggery Pops, the primary ingredients were jowar and jaggery. Jowar, priced at ₹20 per 200 grams (₹10 per 100g), and jaggery, priced at ₹90 per kilogram (₹4.05 for 45g), brought the total cost per 100g to ₹14.05. No high-cost ingredients such as butter or oil were included, contributing to the product's low production cost

In comparison, the control sample, Caramel Popcorn, had a higher production cost. Corn kernels were priced at ₹42 per 200 grams (₹21 per 100g), sugar at ₹60 per kilogram (₹1.50 for 25g), and butter (Amul, 10g pack) at ₹5. The total cost per 100g amounted to ₹27.50. This analysis indicates that Jowar Jaggery Pops are substantially more cost-effective than Caramel Popcorn, primarily due to the use of fewer and more economical ingredients. This cost advantage may enhance its appeal as an affordable, nutritious snacking option.

SAMPLE PRODUCED (100 g)	INGREDIENTS	QUANTITY USED (in g)	MARKET PRICE	COST
Jowar Jaggery Pops (E)	Whole Jowar	100	₹20 /200g	₹ 10
	Jaggery	45	₹90/kg	₹ 4.05
	Total Cost			**₹ 14.05**
Caramel Popcorn (C)	Corn Kernels	100	₹42/200g	₹ 21
	Refined Sugar	25	₹60/kg	₹ 1.50
	Butter	10	₹5/10g pack	₹ 5.00
	Total Cost			**₹ 27.50**

Table 5 : Cost Analysis of sample E and C

4.6 Interpretations made from Statistical analysis

Parameter	Value / Statement
Test Used	Mann–Whitney U Test
Null Hypothesis (H_0)	There is no significant difference in overall acceptability between the samples
U-value	12.5
Critical U-value ($p < 0.05$)	27
p-value	0.00256 (less than 0.05)
Result	Null hypothesis rejected
Interpretation	Significant difference observed; Jowar Jaggery Pops rated more acceptable overall.

Table 6 : Statistical Analysis - Mann-Whitney U Test for Overall Acceptability

To determine whether there was a significant difference in overall acceptability between the experimental (Jowar Jaggery Pops) and control (Caramel Popcorn) samples, a Mann–Whitney U test was conducted. This non-parametric test compares differences between two independent groups when the data are rank based and the sample size is small.

The U-value, a test statistic used to evaluate the degree of separation between the two distributions, was 12.5. This was lower than the critical value of 27 at $p < 0.05$, indicating a statistically significant difference between the two samples. The associated p-value was 0.00256, confirming the result's significance.Since the p-value is below 0.05, the null hypothesis (that there is no difference in overall acceptability between the two products) is rejected.

This approach aligns with methodologies used in research by Darmon *et al.,* (2005) who developed a scoring system to estimate the nutritional adequacy of fruits and vegetables and found the three scores (nutrient adequacy, nutrient density, and nutrient-to-price) to be non- normally distributed. They appropriately reported median scores and used the Mann–

Whitney U test to determine if there were statistically significant differences between fruits and vegetables and other foods on all three scores.

Therefore, the results obtained in the current study confirm a statistically significant difference in panelist preference, with Jowar Jaggery Pops being significantly more acceptable than Caramel Popcorn.

4.7 Product Attribute associations with Consumer Perception and Purchase Intent likelihood based on CATA Analysis

The Check-All-That-Apply (CATA) analysis was conducted among the panel members of sensory evaluation (n=10) to assess how consumers perceived the experimental (Jowar Jaggery Pops) and control (Caramel Popcorn) products across various dimensions: nutritional benefits, product characteristics, emotional connection, and purchase intent. This approach aligns with findings by Oliver et al. (2018), who demonstrated that CATA produced results comparable to descriptive analysis when evaluating flavor preferences in strawberries, highlighting it as a viable, time-efficient tool for sensory research. Similarly, Piochi et al. (2021) applied CATA to evaluate consumer responses to extra virgin olive oil over time, successfully identifying key attributes linked to consumer acceptance and sensory changes.

4.7.1 Nutritional Benefits

The Nutritional Benefits section in the CATA questionnaire aimed to capture perceived health advantages of each product; however, the responses showed minimal differentiation between health-conscious and general consumers. This lack of contrast likely stems from limited understanding among panelists regarding the actual nutritional profiles of both the experimental (Jowar Jaggery Pops) and control (Caramel Popcorn) samples. Some panelists inaccurately associated caramel popcorn with attributes like “low in calories” and “gluten-free,” suggesting misconceptions or guesswork. Moreover, fewer nutritional attributes were selected for the control sample, potentially influenced by a preconceived notion that caramel popcorn is less healthy, while the millet-based Jowar Jaggery Pops were perceived as healthier by default. These findings reflect how consumer perceptions are often shaped by assumptions rather than informed knowledge, underscoring the need

for clearer communication of nutritional benefits in functional food promotion.

Therefore, by tallying the most frequently selected attributes for each product, with respect to product characteristics and emotional associations with both samples, key differences in consumer perception were identified.

4.7.2 Product Characteristics

The analysis of product characteristics revealed clear contrasts in perception between the experimental and control samples. Jowar Jaggery Pops were frequently associated with attributes such as "Crunchy texture," "Nutty flavor," and "Healthy snack option," reflecting their perceived novelty and health positioning. In contrast, Caramel Popcorn was predominantly linked to "Sweet flavor," "Classic flavor profile," and "Indulgent snack option," indicating its familiarity and indulgence appeal. These distinctions suggest that the millet-based formulation successfully communicated its unique and health-oriented attributes, while the control retained its traditional sensory identity. The number of panel members who voted for each of these attributes that were chosen the most among the list is plottted in the spider chart below :

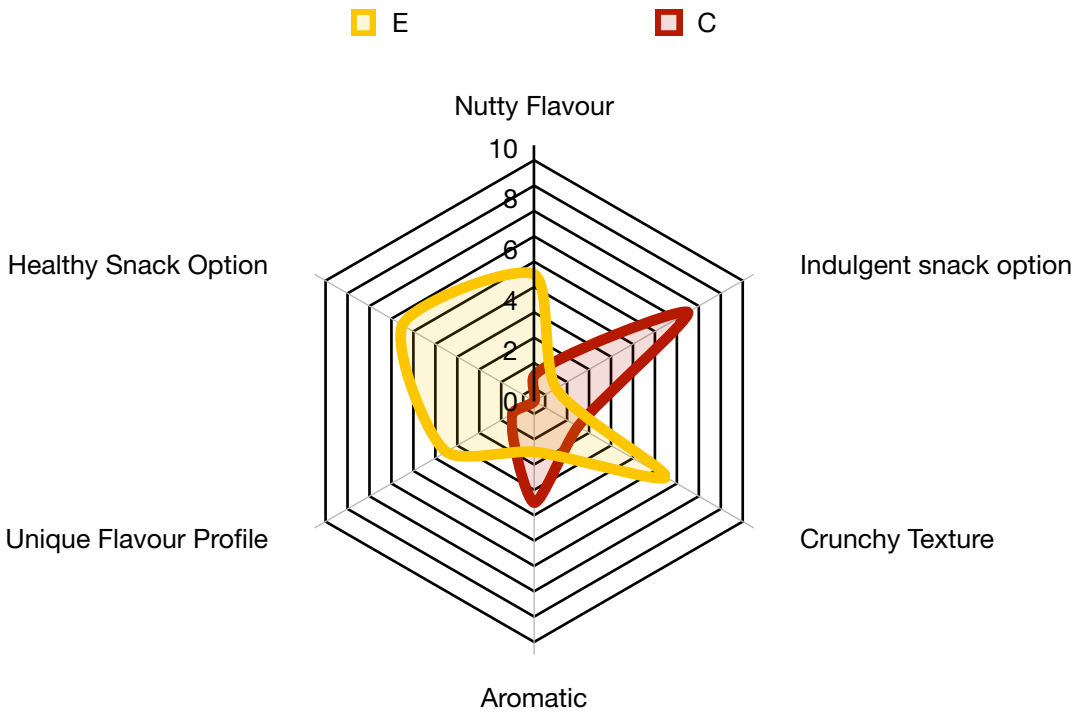

Fig 7: Most picked product characteristics and no.of panelists who associated with them

MOST PICKED ATTRIBUTES	NUMBER OF PANEL MEMBERS (n=10)	
	E	C
Nutty Flavour	5	1
Indulgent Snack Option	1	7
Crunchy texture	6	2
Aromatic	2	4
Unique Flavour Profile	4	1
Healthy Snack Option	6	0

Table 7 : Most picked product characteristics in E and C and no.of panelists who associated with them

4.7.3 Emotional Connection

In terms of emotional connections, panelists associated Jowar Jaggery Pops with feelings of trying something new and making a healthy snack choice, highlighting curiosity and perceived nutritional value. Caramel Popcorn, on the other hand, was tied to indulgence, nostalgia, and being a treat,reflecting emotional comfort and familiarity. This difference reinforces the influence of product background and positioning in shaping emotional responses, with the experimental product triggering exploratory and health-driven sentiments, and the control evoking hedonic and experiential responses.

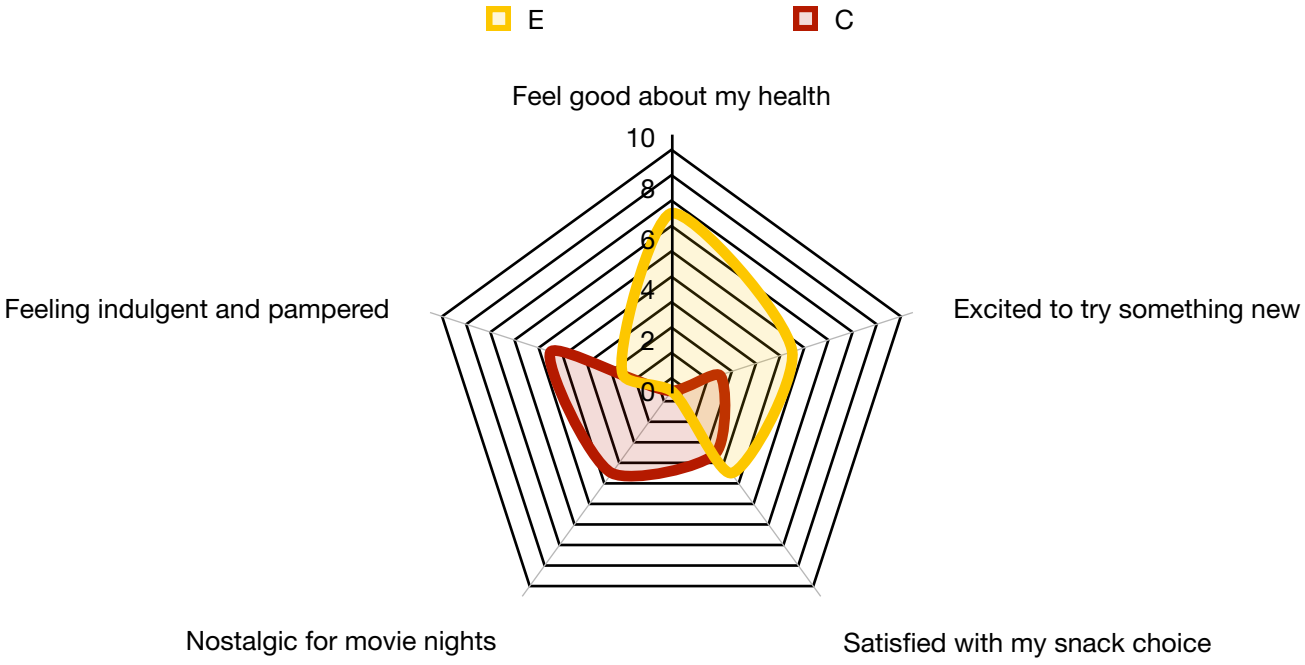

Fig 8 :Most picked emotional associations and no.of panelists who connected with them

MOST PICKED ATTRIBUTES	NUMBER OF PANEL MEMBERS (n=10)	
	E	C
Feel good about my health	7	0
Excited to try something new	5	2
Satisfied with my snack choice	4	3
Feel indulgent and pampered	2	5
Nostalgic for movie nights	0	4

Table 8 : Most picked emotional associations in relation to E and C and no.of panelists who connected with them

4.7.4 Purchase Intent

The purchase intent results indicated a consistently higher willingness to purchase Jowar Jaggery Pops compared to Caramel Popcorn among the panelists. While both products received positive responses, the experimental product had more frequent ratings of "Very Likely" and "Likely." This suggests that health positioning and novelty may have positively influenced consumer interest. In contrast, while Caramel Popcorn is familiar and indulgent, it may not align with current health-conscious snacking trends.

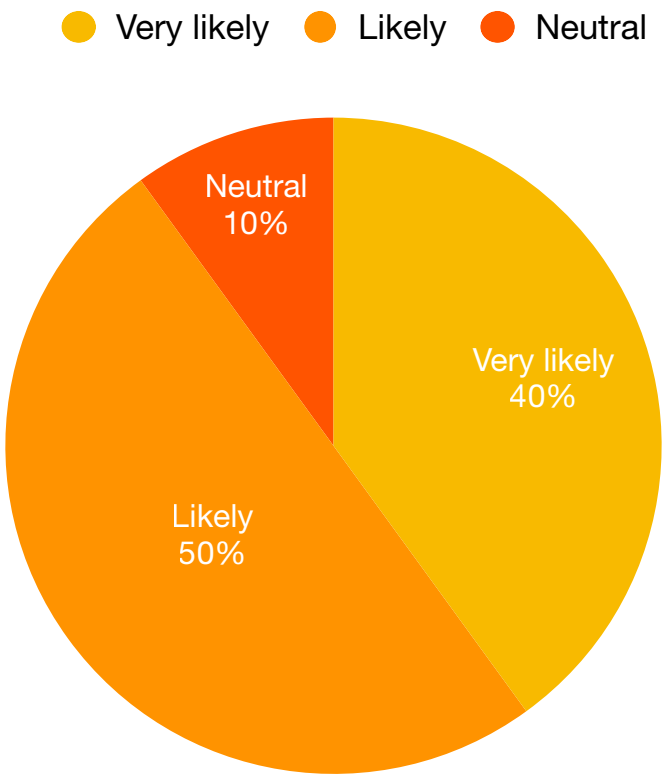

Fig 9: Purchase likelihood (E)

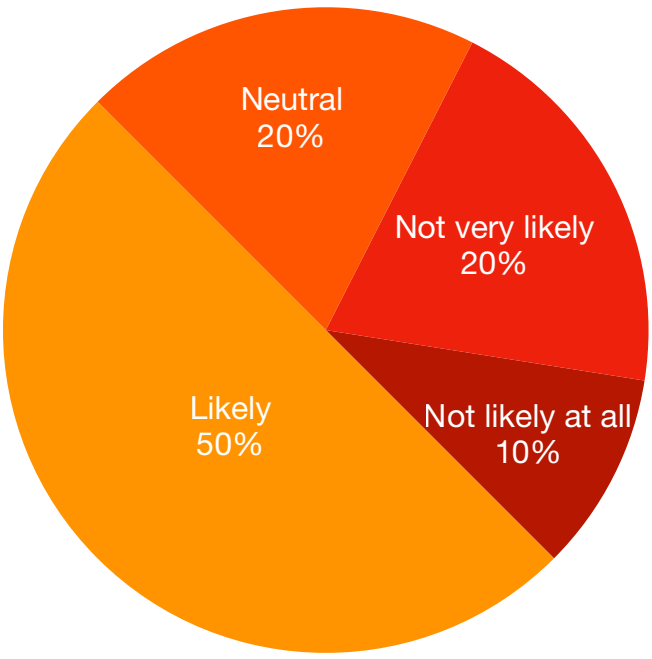

Fig 10: Purchase likelihood (C)

5. SUMMARY AND CONCLUSION

The present study was undertaken to develop and evaluate a healthier alternative to conventional caramel popcorn using nutrient-rich traditional ingredients. Jowar Jaggery Pops , formulated using popped jowar and jaggery, served as the experimental product, while caramel popcorn functioned as the control to which it was being compared, while aiming to achieve similar sensory appeal and consumer acceptance. The product development process emphasized using natural sweeteners, like jaggery and minimal processing to align with current consumer trends favoring health-conscious snacking. Standardization trials helped refine the formulation to achieve acceptable sensory quality and consistency. The final product was then evaluated through a series of physicochemical, sensory, and consumer perception analyses.

Organoleptic evaluation was conducted using a 9-point hedonic scale to assess appearance, texture, taste, and overall acceptability (OAA) for both Jowar Jaggery Pops (E) and Caramel Popcorn (C). The panel consisted of 10 members, resulting in a maximum total score of 360 for each product. Jowar Jaggery Pops scored higher across all sensory parameters, particularly in taste (8.7) and overall acceptability (8.5), with a total score of 336/360 and an acceptability of 93.33%. In comparison, Caramel Popcorn received lower scores, especially for texture (6.9), with a total of 291/360 and an acceptability of 80.83%. Based on overall preference, Jowar Jaggery Pops was ranked first, suggesting that a healthier snack option can achieve parity with conventional products in terms of acceptability.

Nutrient analysis further highlighted the superior nutritional profile of Jowar Jaggery Pops, as the nutrient composition per 100g revealed that Jowar Jaggery Pops had a slightly lower energy content (368.5 kcal) compared to Caramel Popcorn (372 kcal). In terms of macronutrients, Jowar Jaggery Pops were marginally lower in carbohydrates (70.8 g vs. 71 g) and fat (4.1 g vs. 4.8 g), but had a higher protein content (12.1 g) compared to Caramel Popcorn (11.2 g). Dietary fiber was also greater in the experimental sample (13.5 g) relative to the control (12.8 g), indicating better digestive benefits.Micronutrient analysis showed that Jowar Jaggery Pops were richer in iron (22.5 ppm) and calcium (0.6%) than Caramel Popcorn (17.5 ppm iron, 0.5% calcium), reinforcing its nutritional superiority.

Furthermore, the moisture content of Jowar Jaggery Pops was slightly lower (18.5%) than that of Caramel Popcorn (20%), which may contribute to a better shelf stability. The use of traditional millet and unrefined sweeteners contributed to this enhancement, supporting the product's positioning as a functional and culturally relevant snack.

Shelf-life analysis over a defined storage period of 30 days demonstrated that the experimental product maintained acceptable physicochemical and sensory qualities with minimal degradation, supporting its viability for market distribution. Jowar Jaggery Pops maintained superior shelf-life stability compared to Caramel Popcorn, retaining texture and aroma without significant deterioration for up to 7 days. In contrast, Caramel Popcorn showed early signs of spoilage, including aroma changes and softening, possibly due to uneven caramel coating and moisture absorption. While no microbial growth was observed, conclusions remain sensory-based due to lack of microbial testing.

The preparation time for Jowar Jaggery Pops was significantly longer due to preliminary soaking and jaggery integration, totaling over 3 hours as this step contributed to improved puffing quality and nutritional retention. In contrast, Caramel Popcorn required only around 15 minutes reflecting modern convenience. The trade-off highlights a need for balance between health value and time efficiency and the need for optimization in jowar processing to improve feasibility for regular or commercial use.

The cost analysis revealed that Jowar Jaggery Pops (₹14.05/100g) were significantly more economical than Caramel Popcorn (₹27.50/100g). This was primarily due to the use of minimal, affordable ingredients in the experimental product, suggesting better cost-effectiveness and potential market viability.

The Mann–Whitney U test revealed a statistically significant difference in overall acceptability between Jowar Jaggery Pops and Caramel Popcorn ($p = 0.00256$). This indicates that panelists had a clear preference, favoring the experimental product over the control.

The CATA analysis highlighted distinct consumer perceptions between the experimental and control products. Jowar Jaggery Pops were associated with health-oriented and novel attributes such as "Nutty flavor," "Crunchy texture," and "Healthy snack option," while

Caramel Popcorn was linked to indulgent traits like “Sweet flavor” and “Classic flavor profile.” Emotional connections further reinforced this divide—Jowar Jaggery Pops evoked curiosity and health-consciousness, whereas Caramel Popcorn triggered nostalgia, movie nights indulgence. These contrasts suggest that product familiarity, sensory appeal, and perceived health value significantly influence consumer impressions. Notably, perceived nutrition did not always align with actual knowledge, indicating a gap between assumption and fact in consumer choices.

Based on the 5-point Likert scale evaluation, used to assess Purchase intent, Jowar Jaggery Pops showed strong consumer interest, with 50% of panelists indicating they were likely to purchase and 40% very likely, while only 10% remained neutral. In contrast, Caramel Popcorn received a moderate response, with 50% indicating likely, but only 20% remained neutral, and 30% expressed low purchase intent (not very likely or not likely at all). This suggests a stronger inclination toward the experimental product.

In conclusion, Jowar Jaggery Pops presents a promising alternative to conventional caramel popcorn by offering superior nutrition, sensory appeal, cultural relevance, and competitive affordability. This study underscores the importance of balancing health benefits with sensory satisfaction and emotional connection in food product development. It also reinforces the insight that while nutritional benefits are appreciated, they alone do not guarantee consumer acceptance—highlighting the need for a multidimensional evaluation approach in designing successful health-oriented snack products.

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APPENDIX I

SENSORY EVALUATION CARD

NAME OF PARTICIPANT :

DATE :

Instructions to follow :

- Please rinse your mouth with water before starting.
- You may rinse your mouth again at any time during testing if you need to.
- Please taste the two samples in order presented from left to right.
- You may re – taste the samples once you have tried all of them
- Score the samples.

9 Point Hedonic Score Rating Card :

SENSORY CHARACTERISTICS	JOWAR JAGGERY POPS	CARAMEL POPCORN
Appearance		
Texture		
Taste		
Overall Acceptability		

Please evaluate the sensory attributes of each sample by rating them according to your perception, from a scale of 1-9, where :

9 = Like extremely

8 = Like very much

7 = Like moderately

6 = Like slightly

5 = Neither like or dislike

4 = Dislike slightly

3 =Dislike moderately

2 = Dislike very much

1 = Dislike extremely

SIGNATURE OF THE PARTICIPANT

THANK YOU FOR PARTICIPATION

APPENDIX II

Product Attribute Evaluation Using CATA (Check-All-That-Apply) Analysis: Assessing Consumer Perception of Product Attributes

Please evaluate the following two products:
1. Jowar Jaggery Pops
2. Caramel Popcorn

Nutritional Benefits:

Which of the following nutritional benefits do you associate with each product? (Select all that apply for each product)

Jowar Jaggery Pops:
- ○ High in fiber
- ○ Good source of protein
- ○ Rich in antioxidants
- ○ Gluten-free
- ○ Low in calories
- ○ High in minerals
- ○ Supports digestive health
- ○ Other (please specify): _____

Caramel Popcorn:
- ○ High in fiber
- ○ Good source of protein
- ○ Rich in antioxidants
- ○ Gluten-free
- ○ Low in calories
- ○ High in minerals
- ○ Supports energy production
- ○ Other (please specify): _____

Product Characteristics:

Which of the following characteristics do you associate with each product? (Select all that apply for each product)

Jowar Jaggery Pops:
- ○ Crunchy texture
- ○ Sweet flavor
- ○ Nutty flavor
- ○ Healthy snack option
- ○ Sustainable product
- ○ Unique flavor profile
- ○ Aromatic

- Other (please specify): _____

Caramel Popcorn:
- Crunchy texture
- Sweet flavor
- Salty flavor
- Indulgent snack option
- Popular at movies
- Classic flavor profile
- Buttery
- Other (please specify): _____

Emotional Connection :

Which of the following emotions do you associate with each product? (Select all that apply for each product)

Jowar Jaggery Pops:
- Feel good about my health
- Excited to try something new
- Connected to traditional cuisine
- Satisfied with my snack choice
- Other (please specify): _____

Caramel Popcorn:
- Feel indulgent and pampered
- Nostalgic for movie nights
- Excited for a special treat
- Satisfied with my snack choice
- Other (please specify): _____

Purchase Intent:

How likely are you to purchase each product?
1. Jowar Jaggery Pops: _____
2. Caramel Popcorn: _____

Kindly indicate your rating between a scale of 1-5, where :

5 = Very likely
4 = Likely
3 = Neutral
2 = Not very likely
1 = Not likely at all