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Sensory Evaluation and Consumer Acceptance of Pearl Millet (Bajra) Cookies among School-Going Children

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Abstract
Childhood malnutrition persists as a major public health issue in developing countries because both undernutrition and micronutrient deficiencies continue to hinder children's growth and learning capacity and development of their immune systems. The main types of nutritional deprivation found in children show particular danger through hidden hunger because children can eat enough food yet their bodies remain deficient in essential micronutrients such as iron and zinc and calcium and dietary fiber. The existing imbalance produces immediate effects that impact physical development and cognitive performance and school attendance. The cereal crop known as pearl millet (Pennisetum glaucum) which people call Bajra shows promising potential because it contains nutrients and grows well under extreme weather conditions. The product provides a natural source of iron and fiber together with essential minerals which makes it suitable for use in functional foods intended for children. Bajra maintains higher nutritional value than refined wheat yet it remains absent from common pediatric snack options because its rough texture and dark color and mild earthiness make it difficult for children to accept.

The present study examined the sensory characteristics and consumer acceptance of pearl millet-based cookies compared with traditional refined wheat cookies among school-going children aged 8–12 years (n⓶=120). The cookies evaluation process used a 9-point Hedonic scale which assessed their color and aroma and texture and taste and overall acceptability. The results showed that refined wheat cookies were preferred in terms of appearance and texture, while pearl millet cookies performed competitively in taste and overall acceptability, especially in the blended formulation. The 50:50 composite cookie formulation achieved a favorable balance.

Keywords: *Pearl Millet (Pennisetum glaucum), Childhood Malnutrition, Sensory Evaluation, Consumer Acceptance, Functional Foods*

I. Introduction

The world has shifted its dietary practices from traditional regional food systems toward industrialized food systems which offer standardized meal options this change has created nutritional deficiencies that affect children. School-going children experience critical development because they grow physically while their brains develop and they need more nutrients. Children need to consume protein, iron, zinc, calcium, and fiber during this time to support their growth and cognitive abilities and their ability to concentrate and their protection against diseases. Children today eat too much refined snack foods which contain high sugar levels and low vitamin content and have weak dietary fiber structure. The products taste good and look nice but they provide almost no nutritional value to the body. The developing countries face worsening problems because their citizens experience food shortages and limited access to diverse foods and processed foods gain more popularity.

The children will eat enough food to meet their basic needs but their bodies will still lack essential vitamins and minerals. The phenomenon called “hidden hunger” remains undetected for extended periods yet it leads to severe damage throughout time. Iron deficiency leads to decreased concentration and learning capacity while zinc deficiency results in reduced physical development and weaker immune protection. People are now recognizing the connection between inadequate fiber intake and digestive problems which lead to unhealthy eating habits throughout their entire life. The creation of low-cost nutritious snacks which children will enjoy eating needs to become the top priority for public health organizations.

The historical record shows that pearl millet which people call Bajra stands as the oldest cultivated cereal in both South Asia and Africa. The crop has gained recognition as a "super-cereal" because of its ability to endure difficult conditions and its valuable nutritional properties. The crop functions as a C4 plant which enables it to grow well in hot dry environments that have poor soil conditions for wheat and rice farming. The solution provides ideal conditions for areas that experience both climate changes and water shortages. The

nutritional value of pearl millet exceeds its farming benefits. The food contains high amounts of iron protein magnesium phosphorus and dietary fiber which results in a better micronutrient profile compared to refined wheat. Bajra serves as a staple grain in traditional diets while urban and school settings consider it to be unrefined and less appealing than refined wheat products.

The essential obstacle that prevents people from choosing millet-based foods exists in the way that people perceive the food's sensory qualities. Children demonstrate high sensitivity toward three specific sensory attributes which include food texture and appearance and flavor. Children show a preference for baked products that have soft texture and light color and mild sweetness. Bajra flour alone creates baked goods that have a denser crumb structure and produce darker baked goods with an aftertaste that contains natural polyphenols. The food contains nutritional advantages but people do not accept it because of these characteristics. Children show greater acceptance of millet products when manufacturers use formulation strategies that include partial wheat flour substitution and flavor enhancer addition and processing methods which improve mouthfeel.

The researchers wanted to find out if Bajra could be used to make cookies that would still attract customers to buy the product. The researchers used cookies for their study because children already know about them and find them easy to eat. The researchers used wheat-based cookies and blended cookies and 100 percent pearl millet cookies to measure how food tastes and its nutritional value. The researchers wanted to find out if Bajra-based cookies could serve as a practical solution for school nutrition programs and public health initiatives.

II. Materials and Methods

2.1 Raw Material Procurement

Researchers acquired high-quality pearl millet grains which they processed through cleaning and decortication procedures to decrease anti-nutritional compounds while boosting milling performance. The grains were then processed into flour through a milling process which used a 100-mesh sieve to create particles that met the requirements of cookie manufacturing. The researchers acquired refined wheat flour from the local market which serves as the primary ingredient in commercially produced bakery goods to function as their control component. The researchers created three different cookie recipes which they used for their comparison. The first sample which served as the control contained only refined wheat flour without any other components. The second sample consisted of a composite blend which contained equal parts refined wheat flour and pearl millet flour. The complete formula used to create the third product consisted only of pearl millet flour. The research design enabled researchers to evaluate sensory acceptance between complete product replacement and partial product substitution methods.

2.2 Cookie Formulation

The researchers used a standard creaming method to create all cookie samples which produced consistent results throughout their baking process. The recipe contained fat and sugar in fixed quantities to create a uniform base that would not bias the results due to differences in sweetness or richness. The creaming process started with hydrogenated vegetable fat and powdered sugar which were mixed together before adding dry ingredients that contained flour and sodium bicarbonate to function as a leavening agent. The team created circular dough pieces which they baked at 180 degrees Celsius for 15 minutes to make cookies.

All products were tested under identical baking conditions which allowed researchers to link different baking results directly to flour types used instead of any changes that occurred during the baking process. The cookies required cooling time until they reached room temperature before researchers could conduct their sensory evaluations. The process preserved texture stability which blocked heat from affecting participants' responses during the evaluation process.

2.3 Sensory Panel and Environment

The sensory evaluation panel consisted of 120 school-going children aged 8–12 years from three local primary schools. This age group was selected because children at this stage are old enough to express reliable food preferences yet still represent the target population for school nutrition interventions. The researchers conducted sensory tests during mid-morning break time when students were able to test food in a neutral setting which prevented hunger and classroom conditions from affecting their performance.

The researchers presented each sample on coded plates which helped to decrease bias while stopping participants from figuring out the sample contents. The researchers provided water to participants between samples so they could cleanse their palate and decrease the effects of previous samples. The children used a 9-point Hedonic scale to evaluate each cookie which assigned 1 to "dislike extremely" and 9 to "like extremely" as endpoints. The researchers evaluated five different properties of the product which included color and aroma and texture and taste and overall acceptability. This method has become an essential tool in food science because

it enables researchers to measure consumer preferences through a method that both children and adults can easily understand.

III. Results and Discussion

3.1 Sensory Profile Analysis

The three cookie formulations showed distinct differences which were demonstrated through sensory scoring. The refined wheat control obtained the highest ratings across most attributes, especially texture and appearance, which is consistent with the soft, uniform, and light-coloredstructure which bakery products made from maida possess. The 50% pearl millet blend performed well across all categories and often came close to the control, suggesting that moderate millet incorporation may be well tolerated by children. The 100% Bajra cookie received lower scores in appearance and texture, but it still maintained respectable acceptance in taste and overall liking.

The millet cookies received lower appearance scores because their darker rustic color created a visual contrast with the pale golden tone of refined wheat cookies. Children often associate lighter foods with sweetness, softness, and familiarity, so a darker product may initially be perceived as less appealing. Preference showed a strong connection to texture. The millet cookies were described as denser and more crumbly, which showed how gluten absence resulted in loss of elasticity and structure which normally exists in wheat-based doughs. The blended cookie showed that users could use some of the textural constraints, which arise from gluten absence, by combining the nutritional advantages of millet with the preferred baking properties of wheat.

Flavor emerged as one of the more encouraging findings. The 50:50 blend received positive feedback from most participants while the control sample received slight preference from the test group. The results show that millet maintains its taste appeal when used in equal proportions with other ingredients. The natural nutty taste of Bajra which exists at moderate levels, helps create positive consumer impressions about the product. The development process of products requires this information because it allows designers to create millet-based snacks which maintain good taste while achieving higher nutritional content.

3.2 Discussion of Attributes

The various sensory characteristics of millet-based baked goods enable researchers to understand how children experience these products. The 100% Bajra cookies experienced their greatest restriction because of their texture. Gluten absence leads to weak bond formation which results in a sandy or gritty mouthfeel. Children who grow up eating soft commercial cookies will find this quality less appealing than traditional snack products. The partial replacement formula produced better results because wheat flour added elasticity which enhanced the cookie's structural strength. Color also played an important role in acceptance. Children consistently preferred the lighter and more familiar appearance of wheat cookies. The darker grey-brown Bajra cookies color indicates reduced sweetness according to others who perceive the cookies as less refined. The study shows that children do not select nutritious foods because these foods do not match their visual expectations. The upcoming product development process will require teams to use ingredient blending and surface glazing and cocoa-based masking to create better visual product designs.

The most valuable quality of millet cookies was their taste because it became their most exceptional characteristic. The 50% blend performed nearly as well as the control which showed that Bajra can be used without losing its taste when used with proper measurement. The combination of sugar and fat with pearl millet's earthy flavors creates a taste experience that develops more complex flavors. The research shows that sensory acceptance of a product can be improved through scientific product development methods because it operates as a mutable quality. Children will first refuse to eat food that appears different to them but they will accept it after they taste its flavor and experience its texture.

3.3 Nutritional Significance

From a nutritional standpoint, pearl millet cookies clearly offer important advantages over refined wheat cookies. The PM-100 formulation delivered three times the iron content and double the fiber content when compared to the control. The two differences between these two groups have significant value because even small increases in micronutrient consumption help children achieve better health results through their standard dietary patterns. The millet cookie provides children with a substantial portion of their daily iron needs but the wheat cookie offers much smaller amounts.

Iron deficiency remains one of the most common nutrient deficiencies found among school-aged children because it affects their nutritional needs. Low iron intake can lead to fatigue, poor concentration, irritability, and reduced academic performance. Pearl millet serves as an effective solution to increase micronutrient intake because it naturally contains higher iron levels than refined wheat. Pearl millet provides essential nutrients because its fiber content helps children who consume insufficient whole grains and roughage.

Higher fiber intake supports digestion, satiety, and better regulation of blood glucose levels, which may help reduce excessive snacking.

The mineral profile of Bajra makes it applicable to wider school health programs. The grain contains not only iron but also zinc and magnesium and phosphorus, which all serve essential functions for both growth and metabolic processes in the human body. The millet cookies function as more than just a snack option because they serve as a food product with nutritional benefits. The program provides a solution to tackle several deficiencies at once, especially when utilized in school feeding and mid-day meal initiatives.

Attribute	Control (100% Wheat)	PM-50 (50% Wheat + 50% Bajra)	PM-100 (100% Bajra)	Interpretation
Color/Appearance	8.5	8.1	7.4	Wheat was visually preferred, while Bajra produced a darker, more rustic look ijirt+1.
Aroma/Smell	8.2	7.9	7.6	Bajra maintained acceptable aroma, but the wheat control remained slightly more familiar ijirt+1.
Texture/Crunch	8.7	7.8	6.9	Texture declined with higher Bajra substitution because of reduced gluten and a more crumbly bite myfoodresearch+1.
Taste/Flavor	8.6	8.2	7.8	The 50% blend preserved good flavor while adding a mild nutty millet note ijirt+1.
Overall Acceptance	8.5	8.0	7.4	Partial substitution gave the best balance of acceptability and nutrition najfnr+1.

Table: 1

3.4 Challenges and Optimization Strategies

The results show positive outcomes, but the study still faces unresolved sensory limitations. The 100% pearl millet cookie did not achieve the same level of acceptance as the wheat or blended cookies, primarily because of texture and appearance. The statement shows that products made from millet do not meet children's needs because they require changes to their product design to become more appealing to customers.

The effective strategy requires pre-treatment of millet flour. Soaking and blanching together with mild heat treatment process help decrease lipase activity which results in reduced bitterness and better shelf stability. Processing methods which decrease anti-nutritional components enable better nutrient absorption while they also reduce unwanted taste elements. Flavor masking stands as another practical solution. The combination of cocoa powder with cardamom and vanilla and mild fruit flavors creates a flavor that reduces the earthy taste of millet while making the final product more appealing to children. The bakery industry can easily use these cost-effective ingredients which customers already know and which they can add to their existing products.

The most practical solution for composite flour functions as the ideal middle ground between two extremes. The 50:50 blend achieves an optimal nutritional balance which people will accept so public health benefits can be achieved without needing to completely replace existing foods. The dietary quality of most places will improve when people partially switch to Bajra products which they will still accept. Large-scale institutional feeding programs need this approach because they require widespread public acceptance. The product development process should first find the best millet-wheat ratio before deciding to replace all millet content with wheat.

3.5 Public Health and Programmatic Relevance

The study results create direct applications which will shape both nutrition policy development and child feeding program design. School feeding programs deliver nutrient-enriched foods because they serve children who need proper nutrition during their developmental stage and they help children establish long-term eating patterns. Mid-day meals and supplementary feeding schemes and school snack programs should include bajra cookies as an additional food option. The products meet institutional requirements because they remain safe to use over long periods and their design enables simple implementation of operational procedures.

Millet-based snacks provide public health advantages which extend beyond their nutritional value. The products benefit local farmers because they promote agricultural diversity while decreasing the need for processed grains. Pearl millet serves as an environmentally sustainable crop solution which becomes essential during a time when climate resilience has gained importance. Supporting its use in child-friendly products could therefore produce benefits across nutrition, agriculture, and food security simultaneously.

Nutrient aspect	Wheat cookies	Bajra cookies	Relevance
Iron	Lower	Higher	Pearl millet is a strong natural source of iron and can help address anemia risk millets.res+1.
Fiber	Lower	Higher	Higher fiber supports satiety and digestive health millets.res+1.
Mineral density	Moderate	Strong	Bajra improves micronutrient density for school snacks millets.res+1.
Consumer	High for	Higher in blend	A 50:50 blend improves acceptance without losing nutritional value

appeal	texture	form	najfnr+1.

Table: 2

IV. Conclusion

Pearl millet cookies serve as a nutritious alternative which schools can offer to children instead of traditional wheat-based snacks. The 100% millet product failed to meet texture and appearance standards yet showed nutritional benefits together with acceptable taste. The 50:50 composite formulation proved that Bajra can be used in existing bakery products without losing major customer appeal. Schools need this equilibrium because students must find their food appealing while enjoying its health advantages.

The research shows that pearl millet cookies offer effective school nutrition solutions for regions dealing with both micronutrient shortages and food scarcity. The right processing followed by product development and flavor design will enable Bajra to become a contemporary functional food which doctors can recommend to children. The proposed method will enhance dietary standards while advancing sustainable farming practices and furthering public health objectives.

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