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Formulation and development of high protein, gluten free soda crackers enchriched with *Pithecellobium Dulce* aril powder

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Abstract
This study developed and evaluated gluten-free soda crackers enriched with *Pithecellobium Dulce* (Manila tamarind) aril powder. The crackers, formulated with a blend of gluten-free flours and P. dulce powder, showed improved nutritional profiles, including increased protein, crude fiber, and reduced glycemic index. Physical properties and sensory qualities were also enhanced, with samples T^2 and T^3 receiving high scores for color, aroma, crunchiness, taste, and overall acceptability. The addition of P. dulce aril powder improved the nutritional and sensory qualities of the crackers, making them a nutritious and acceptable alternative to traditional gluten-containing crackers. This study highlights the potential of P. dulce as a valuable ingredient in gluten-free baking, offering a convenient and nutritious food product for individuals with celiac disease or gluten intolerance.

Keywords: Manila tamarind, baking, gluten free, celiac disease, glycemic index

Introduction
The demand for gluten-free products has been increasing rapidly due to the growing prevalence of gluten-related disorders, such as celiac disease and gluten intolerance. Gluten-free soda crackers are one such product that can be manufactured using a blend of gluten-free flours. However, the addition of other grains and ingredients can enhance the nutritional value, taste, and health benefits of these crackers. Nutrition and taste must go hand in hand if one is to lead a healthy lifestyle.

Crackers are thin and crisp products baked from unsweetened and unleavened dough. Based on the ingredients and production methods. the difference of baked cracker before and after baking to the thickness of cracker dough, is an important indicator of cracker quality. Sedej *et al*. (2011) [22] prepared gluten-free crackers with buckwheat in either refined (8.34% protein) or wholegrain (10.5% protein) forms and compared the antioxidant properties with wheat cracker. Crackers made from buckwheat exhibited higher total phenolic and total tocopherols contents and DPPH radical scavenging activity in contrast to the wheat cracker.

Pithecellobium Dulce, also known as Manila tamarind, is a fruit rich in nutraceutical properties, including antioxidants, anti-inflammatory compounds, and essential vitamins and minerals. Despite its nutritional benefits, the fruit is highly perishable, resulting in significant post-harvest losses. The incorporation of P. dulce fruit powder into gluten-free crackers can enhance their nutritional value and acceptability.

The use of composite flour, including buckwheat, soy, sweet potato, and rice flour, can provide a balanced mix of nutrients and improve the texture and taste of gluten-free crackers. Buckwheat flour is a good source of protein and antioxidants, while soy flour is rich in protein and isoflavones. Sweet potato flour is rich in starch, protein, vitamins, and minerals, and contains bioactive phytochemicals that exert antioxidant. Rice flour is a good substitute for wheat flour and can be used as a thickening agent in recipes.

Gluten free soda crackers are one such product manufactured using the technique. However, the addition of other grains in the product enhance the nutritive value of the composite flour (buckwheat, soy, sweet potato& rice flour) along with the taste and health benefits. Nutrition and taste must go hand in hand if one is to lead a healthy lifestyle.

Taking all these points into consideration the following research was taken up with the objective of studying the physicochemical properties of P. dulce, aril and to develop P. dulce fruit powder. The development of gluten-free soda crackers enriched with P. dulce fruit powder can provide a nutritious and acceptable food product for individuals with gluten intolerance or celiac disease. The objectives of this research are to evaluate the physicochemical properties of P. dulce aril, develop a gluten-free cracker product enriched with P. dulce fruit powder, and assess the nutritional, sensory, and quality attributes of the developed crackers.

Composite flour

Buckwheat flour: The incorporation of buckwheat can be justified in composite flour based crackers as it has beneficial nutraceutical properties and its gluten-free nature can play important role in preventing celiac problem. It's adds diversity of texture, taste and appearance to food products.

Soya flour: Soya flour is made from soya beans after the oil has been extracted. Soya flour is a source of protein and contains a small amount of the emulsifier lecithin. Soya flour is a valuable ingredient in some dietary and gluten-free biscuits.

Sweet potato flour: Sweet potatoes are rich in starch, protein, vitamins, minerals, and fiber. Moreover, they contain bioactive phytochemicals such as polyphenols that exert antioxidant and anticancer effects. Sweet potato flour can enhance flavor and texture, increase nutritional value, and improve dough structure and crispiness.

Rice flour: Rice flour is a particularly good substitute for wheat flour, which some people believe irritates their digestive system. Rice flour is also used as a thickening agent in recipes that are refrigerated or frozen. Rice flour can be used as a thickener for soups, stews, gravies, and sauces. It creates a smooth, silky texture without imparting strong flavors.

This study will contribute to the development of nutritious and acceptable gluten-free products, utilizing P. dulce as a valuable ingredient. The findings will have implications for the food industry, particularly in the development of products catering to individuals with gluten-related disorders. By exploring the potential of P. dulce fruit powder in gluten-free baking, this research aims to provide a new perspective on the development of healthy and nutritious food products.

The significance of this study lies in its potential to address the growing demand for gluten-free products and to provide a nutritious and acceptable food option for individuals with gluten intolerance or celiac disease. The study's findings will also contribute to the growing body of research on the nutritional and health benefits of P. dulce and its potential applications in food product development.

Objectives

This study was planned with the objectives

1. To develop and standardize high protein gluten-free soda crackers incorporated with *Pithecellobium Dulce* aril powder.
2. To evaluate physicochemical properties of the soda crackers.
3. To evaluate Sensory and Microbial properties of the soda crackers.

Materials and Methods

The present research study was conducted in the Dr. NTR College of Food science and Technology, ANGRAU, Bapatla. The study was conducted on "Formulation and Development of High Protein, Gluten Free Soda Crackers Enchriched With *Pithecellobium Dulce* Aril Powder Gluten free soda crackers incorporated with monkey pod aril powder and analysed for their Physico-chemical properties, cooking properties and sensory properties. The details of the materials and methodologies adopted in this study is presented below: The main ingredients used in the development of gluten free soda cracker incorporated with *P.dulce* aril powder are Rice flour, buckwheat flour, soy flour, sweet potato flour were procured from local market.

Procedure for the preparation of P.dulce Aril powder

The P. dulce fruits underwent a series of processing steps to prepare them for use. Initially, the fruits were sorted and cleaned to remove dirt, stones, straws, grit, and other foreign particles. The fruits were then peeled and deseeded to remove the outer layer and seeds. After peeling and deseeding, the pods were washed with clean water to remove any remaining dirt, debris, and contaminants. The pods were then blanched in hot water (below 100°C) for 4 minutes to preserve their color. Following blanching, the pods were dried in a hot air oven for 13 hours. The dried pods were then milled into a fine powder using a laboratory-scale flour mill. Finally, the powder was packaged in airtight packaging covers to maintain its quality and freshness.

Processing of P.dulce aril Powder

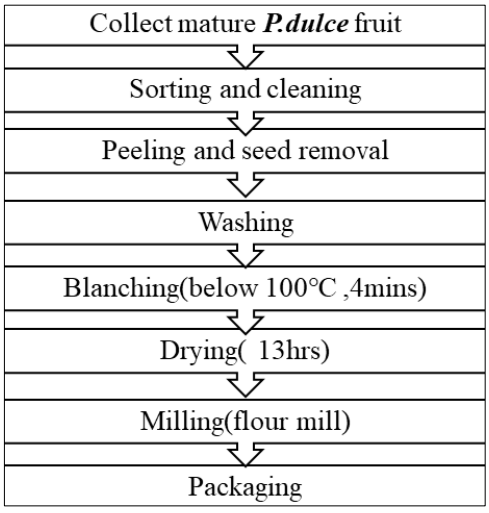

Fig 1: Flow chart on *P. dulce* aril powder processing

Results and discussion

1.Product Evaluation

The composite flour incorporated with *P. dulce* aril powder were analyzed for their cooking qualities, proximate nutrient composition, and organoleptic qualities.

Thickness(mm)

The Thickness for the T_0 (Control), T_1, T_2 and T_3, T_4 of 4, 3.7, 3.5, 3.2, 3mm respectively. Control sample have more thickness compared with T_1, T_2, T_3 & T_4 due to presence of more wheat flour which is rich in gluten protein in control sample compared to other samples.

2. Basic product formulations of Gluten free soda crackers incorporated with *P. dulce* aril powder

The basic formulation for preparation of Gluten free soda crackers incorporated with *P. dulce* powder is presented in Table: 1. five types of samples (T_0, T_1, T_2, T_3 and T_4) had significant difference in monkey pod aril powder, composite flour (rice flour, buckwheat flour, soy flour, sweet potato flour). The *P. dulce* aril powder content increased gradually 2.5g, 5g, 7.5g and 10g in the Samples T_1, T_2, T_3 and T_4 respectively. The composite flour content was increased from 70g, 85g, 90g and 100g in the sample T_1, T_2, T_3 and T_4 respectively.

T0 = Control sample wheat flour only; T_1= gluten free soda crackers with 70% composite flour only, 2.5% of aril powder; T_2= gluten free soda crackers with 80% composite flour, 5% of aril powder and T_3= gluten free soda crackers with 90% composite flour, 7.5% aril powder and; T_4= gluten free soda crackers with composite flour, % aril powder.

3. Proximate analysis of the formulated gluten free soda cracker incorporated with *p. dulce* aril powder

Proximate analysis of the control sample, T_1, T_2, T_3 & T_4 were performed independently by adopting standard AOAC methods (AOAC, 2000). Moisture content was determined by hot air oven method &IR moisture analyzer (AOAC Method 934.01); crude protein by lowry's method (AOAC, 2005); Total Carbohydrate content was determined by phenol sulphuric acid method (AOAC, 2000). Crude fat by Soxhlet extraction method (AOAC Method 963.15); crude fibre by neutralization method (AOAC Method 945.38) and ash content by dry ash method (AOAC Method 923.03).

Table 1: Basic formulation of flours in gluten free soda crackers incorporated with *P. dulce* aril powder

Sl.no	Ingredients	T_0	T_1	T_2	T_3	T_4
1	Refined Wheat flour (g)	100	0	0	0	0
2	Composite flour (rice, buckwheat, soy& sweet potato flours) (g)	0	70	80	90	100
3	P. dulce aril powder (g)	0	2.5	5	7.5	10
4	Sugar powder (g)	3	3	3	3	3
5	Baking soda (g)	1	1	1	1	1
6	Salt (g)	1	1	1	1	1
7	Corn flour (g)	0	8.5	8.5	8.5	8.5
8	Butter (g)	17	8.5	8.5	8.5	8.5
9	Milk (ml)	20	20	20	20	20
10	Vegetable oil (g)	15.3	15.3	15.3	15.3	15.3
	Total (g)	100	100	100	100	100

Table 2: Proximate analysis of the formulated gluten free soda cracker incorporated with p. dulce aril powder:

Parameters	Samples				
	T_0	T_1	T_2	T_3	T_4
Moisture content (%)	4.02 ± 0.54^{a}	5.28 ± 2.11^{a}	5.47 ± 1.67^{a}	5.63 ± 1.48^{a}	6.08 ± 1.12^{a}
Carbohydrates (%)	83.76 ± 0.11^{a}	71.40 ± 2.09^{b}	69.98 ± 1.45^{bc}	67.63 ± 1.41^{cd}	64.97 ± 0.73^{d}
Protein (%)	2.73 ± 0.09^{b}	6.88 ± 2.26^{ab}	7.21 ± 2.00^{a}	8.30 ± 1.45^{a}	9.77 ± 1.30^{a}
Fat (%)	5.89 ± 0.63^{b}	9.71 ± 1.76^{ab}	10.16 ± 1.30^{a}	10.67 ± 1.39^{a}	11.24 ± 1.69^{a}
Ash (%)	2.01 ± 0.74^{a}	1.14 ± 0.87^{a}	1.24 ± 0.45^{a}	1.52 ± 0.12^{a}	1.80 ± 0.93^{a}
Crude fibre (%)	1.55 ± 0.15^{b}	5.55 ± 0.97^{a}	5.92 ± 1.67^{a}	6.13 ± 1.13^{a}	6.22 ± 1.50^{a}

The proximate analysis of the gluten-free soda crackers showed significant variations in moisture content, fat content, ash content, crude fiber, carbohydrates, and protein content.

Moisture content

The moisture content increased with the addition of P. dulce aril powder, ranging from 4.02% in the control sample to 6.08% in T4. This could be due to the higher water absorption capacity of the composite flour.

Fat content

The fat content increased with the addition of P. dulce aril powder, ranging from 5.89±0.63%, in the control sample to 11.24±1.69% in T_4. This could be due to the higher fat content of the P. dulce aril powder.

Ash content

The ash content varied among the samples, with the control sample having the highest ash content (2.01±0.74%,) and T_1 having the lowest ash content (1.14%±0.87%). This could be due to the differences in the mineral content of the composite flour.

Crude fiber

The crude fiber content increased with the incorporated with P. dulce aril powder, ranging from 1.55±0.15%, in the control sample to 6.22±1.50% in T4. This could be due to the higher fiber content of the P. dulce aril powder.

Carbohydrates

The carbohydrate content decreased with the addition of P. dulce aril powder, ranging from 83.76±0.11% in the control sample to 64.97±0.73% in T4. This could be due to replacement of buckwheat flour(pseudo cereal) proportionally in composite flour.

Protein content: The protein content increased with the addition of P. dulce aril powder, ranging from 2.73±0.09% in the control sample to 9.77±1.30% in T4. This could be due to the higher protein content of the P. dulce aril powder.

Physical Analysis

The physical analysis of the gluten-free soda crackers showed significant variations in texture profile analysis and color.

a. Texture profile analysis: The texture profile analysis showed that T_2 had the highest hardness, fracturability, adhesiveness, springiness, cohesiveness, chewiness, and resilience values. This could be due to the optimal combination of composite flour and P. dulce aril powder in T_2.

Table 3: Texture profile analysis of the formulated gluten free soda cracker incorporated with p. dulce aril powder:

Treatment	Hardness	Fracturability	Adhesiveness	Springiness	Cohesiveness	Gumminess	chewiness	Resilience
T_0	251.932	0	-2.482	0.621	0.838	211.007	311.08	0.853
T_1	4.709	824.515	0	0.292	0.517	2.433	0.711	0.437
T_2	91.551	4943.38	-0.315	0.369	0.611	55.939	20.654	0.661
T_3	5.503	792.80	0	0.385	0.220	1.209	0.465	0.155
T_4	6.512	1965.45	0	0.185	0.146	0.948	0.175	0.111

b. Color: The color acceptability was highest for the control sample, while the crumb color slightly decreased for T1, T2, T3, and T4. This could be due to the differences in the color of the composite flour and P. dulce aril powder.

Table 4: Texture profile analysis of the formulated gluten free soda cracker incorporated with p. dulce aril powder:

SAMPLES	L*	a*	b*
T_0	53.62±0.35 [a]	13.47±1.07 [a]	15.45±0.98 [a]
T_1	46.94±5.90 [a]	11.11±1.11 [b]	10.61±3.58 [b]
T_2	46.23±2.20 [a]	10.98±0.23 [b]	7.67±0.83 [b]
T_3	48.41±0.97 [a]	10.51±0.15 [b]	10.78±0.74 [b]
T_4	46.92±0.63 [a]	10.01±0.09 [b]	8.46±0.11 [b]

Sensory Analysis

T_0 (control sample)

T_2 sample

T_1 sample

T_3 sample

T_4 sample

The acceptability of developed gluten free soda crackers incorporated with p. dulce aril powder was evaluated by a testing panel. The hedonic scale was used to determine the acceptability. The sensory panel was comprised of 15 semi-trained members including 10 females and 5 males in the age group of 20-40 years and10 untrained members including 6 females and 4 males. The members were not professional sensory analysts but they were made acquainted with the use of composite scoring scale and the texture parameters to be used for sensory analysis. The attributes evaluated were color, aroma taste, crunchiness, mouth feel, saltiness, crispiness and overall acceptability. Perceived intensities were scored on a hedonic scale

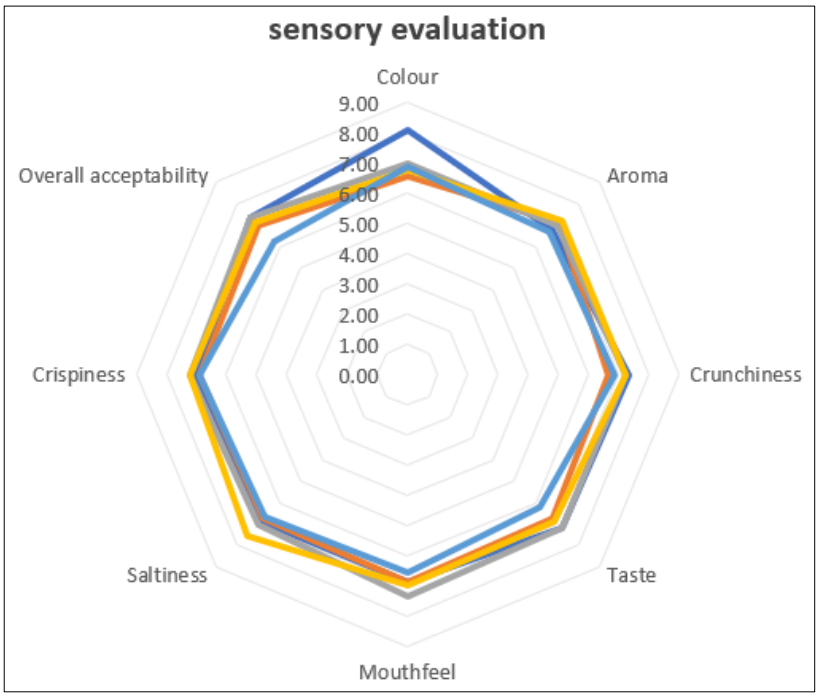

Fig 2: sensory analysis for different samples

The sensory analysis of the gluten-free soda crackers showed that T2 had the highest scores for color, aroma, crunchiness, taste, mouthfeel, saltiness, crispiness, and overall acceptability. This could be due to the optimal combination of composite flour and P. dulce aril powder in T_2.

Conclusion

The study successfully demonstrated the formulation and development of high-protein, gluten-free soda crackers enriched with *Pithecellobium Dulce* aril powder. The incorporation of P. dulce aril powder significantly improved the nutritional profile of the crackers, including increased protein and fiber content, and reduced glycemic index. Samples T_2 and T_3 exhibited superior physical and sensory properties, making them the most preferred among the test samples. The study highlights the potential of P. dulce aril powder as a functional ingredient in gluten-free product formulations, providing a promising avenue for developing nutritious and healthy snack options for individuals with gluten intolerance and health-conscious consumers. Further research is recommended to explore the application of P. dulce aril powder in other food products and assess its long-term storage stability and consumer acceptance.

Furthermore, the study's results suggest that the addition of P. dulce aril powder not only enhances the nutritional profile of the crackers but also improves their sensory qualities. This is a crucial factor in determining consumer acceptance and preference.

In conclusion, the study demonstrates the potential of *Pithecellobium Dulce* aril powder as a valuable ingredient in the development of gluten-free food products.

The successful development of high-protein, gluten-free soda crackers enriched with P. dulce aril powder paves the way for expanding the use of underutilized plant resources in developing health-promoting food products, ultimately contributing to improved public health and well-being.

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