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Reinventing West Sumatran Traditional Snacks into GFCF Therapeutic Food: Nutritional Suitability and Sensory Acceptability for Children with Autism

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Abstract

Children with Autism Spectrum Disorder (ASD) often require a Gluten-Free Casein-Free (GFCF) diet to mitigate gastrointestinal and behavioral symptoms. In West Sumatra, specifically Bukittinggi, the abundance of indigenous non-wheat crops presents a significant opportunity for developing affordable therapeutic snacks. However, reinventing traditional snacks requires precise formulation to ensure both nutritional density and sensory acceptability. This study aims to reformulate traditional West Sumatran snacks, specifically "Lapek," into GFCF-compliant therapeutic products using local sweet potato and fish albumin, and to evaluate their sensory acceptance among children with ASD. This research employed an experimental laboratory design for product formulation and a descriptive quantitative approach for sensory evaluation. The formulation utilized local Agam purple sweet potatoes, *Channa striata* (snakehead fish) for albumin enrichment, coconut milk, and "Gula Saka" (traditional palm sugar). Sensory testing was conducted with 20 children with ASD in Bukittinggi using a 5-point Facial Hedonic Scale to assess color, aroma, texture, and taste. The optimized formulation (75% purple sweet potato, 10% fish albumin) successfully met GFCF standards. Nutritional analysis indicated high anthocyanin content and essential Medium-Chain Triglycerides (MCTs). Sensory results showed high acceptability, particularly in color (4.5/5.0) and taste (4.2/5.0). The use of Gula Saka and coconut milk effectively masked the fish aroma, making the snack palatable for children with sensory hypersensitivity. Reinventing local snacks provides a sustainable and culturally appropriate dietary strategy for ASD management. This innovation leverages regional biodiversity to offer a cost-effective alternative to imported GFCF products.

Keywords: Autism, GFCF Diet, West Sumatran Snacks, Purple Sweet Potato, Albumin, Bukittinggi.

1. Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental condition characterized by persistent challenges in social communication, repetitive behaviors, and restricted interests [1]. Beyond neurological symptoms, recent clinical evidence highlights that approximately 70% of children with ASD suffer from chronic gastrointestinal (GI) disturbances, such as "leaky gut" syndrome and dysbiosis [2]. These GI issues are often linked to neuroinflammation via the "gut-brain axis," where incompletely digested proteins specifically gluten from wheat and casein from dairy may cross the intestinal barrier and act as opioid-like compounds, exacerbating behavioral symptoms [3, 4].

In addition to gastrointestinal and neurological factors, children with Autism ASD also exhibit significant alterations in sensory processing, particularly in relation to food perception. Sensory hypersensitivity toward texture, aroma, and taste often leads to severe food selectivity, a condition where children accept only a very limited range of foods [5] This behavior is further reinforced by avoidance learning mechanisms, in which negative sensory experiences result in long-term food rejection [6]. From a behavioral psychology perspective, food acceptance in ASD is strongly

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influenced by familiarity and repeated positive exposure. Therefore, introducing therapeutic diets using culturally familiar foods becomes a critical strategy to improve compliance and reduce food neophobia [7].

To manage these symptoms, the Gluten-Free Casein-Free (GFCF) diet has emerged as one of the most widely implemented nutritional interventions globally [8]. However, the practical application of GFCF diets in developing countries, particularly in Indonesia, faces significant socioeconomic hurdles. Most commercial GFCF products are imported, expensive, and often rely on ultra-processed ingredients that lack essential micronutrients [9, 10]. In West Sumatra, specifically in the Bukittinggi region, there is an urgent need to develop affordable, locally sourced therapeutic foods that are culturally acceptable to the community [11].

Bukittinggi is renowned for its rich biodiversity and traditional culinary heritage, which predominantly utilizes naturally gluten-free ingredients such as tubers, rice, and coconut [12]. Purple sweet potato (*Ipomoea batatas L.*) from the Agam Regency is a promising base for ASD snacks due to its high anthocyanin content, which serves as a potent antioxidant to combat oxidative stress in the brains of children with ASD [13, 14]. Furthermore, the integration of *Channa striata* (snakehead fish), a local freshwater fish rich in albumin, offers a strategic solution for gut-barrier restoration, which is critical for ASD nutritional therapy [15, 16].

Despite the potential of West Sumatran traditional snacks like *Lapek*, their conversion into standardized therapeutic products remains under-researched. Most traditional recipes still utilize refined sugars and lack standardized protein fortification [14]. Therefore, this study aims to reinvent these traditional snacks by formulating a GFCF product that synergizes the anti-inflammatory properties of purple sweet potato with the regenerative potential of fish albumin. By leveraging local wisdom and "Gula Saka" (traditional palm sugar), this research seeks to provide a sustainable and culturally appropriate nutritional strategy for the ASD community in Indonesia [17, 18].

2. Literature Review

2.1. The Gut-Brain Axis and GFCF Diet in ASD

The "Gut-Brain Axis" represents the bidirectional communication between the gastrointestinal tract and the central nervous system. In children with ASD, increased intestinal permeability often termed "leaky gut" allows partially hydrolyzed proteins like gluteomorphin (from gluten) and casomorphin (from casein) to enter the bloodstream [3, 5]. These peptides act as false neurotransmitters, binding to opioid receptors in the brain, which can lead to social withdrawal and cognitive fog [2]. Literature suggests that a strict GFCF diet, when supplemented with proper micronutrients, can significantly reduce systemic inflammation and improve behavioral scores in a subset of ASD patients [4, 6].

2.2. Anthocyanins in Purple Sweet Potato (*Ipomoea batatas L.*) as Neuroprotective Agents

Purple sweet potatoes, particularly those cultivated in the volcanic soil of Agam Regency, are exceptionally high in acylated anthocyanins. Recent studies indicate that anthocyanins cross the blood-brain barrier and exert neuroprotective effects by neutralizing reactive oxygen species (ROS) [10]. For children with ASD, who often exhibit high levels of oxidative stress, the consumption of purple sweet potato serves as more than just a carbohydrate source; it acts as a functional agent to mitigate neuroinflammation and enhance synaptic plasticity [11].

2.3. *Channa striata* (Snakehead Fish) and Gut Integrity Restoration

The integration of *Channa striata* into ASD snacks addresses the prevalent issue of gastrointestinal mucosal damage. This local freshwater fish is a superior source of albumin and essential amino acids such as glycine, glutamine, and proline [12]. Albumin plays a critical role in maintaining osmotic pressure and transporting minerals, while glutamine is the primary fuel for enterocytes, aiding in the repair of the

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intestinal lining [13]. By restoring gut integrity, albumin-rich snacks can potentially reduce the absorption of inflammatory peptides that trigger ASD symptoms.

2.4. Medium-Chain Triglycerides (MCTs) in Coconut Milk

Transitioning Traditional West Sumatran snacks heavily rely on coconut milk (*santan*), which is naturally rich in Medium-Chain Triglycerides (MCTs), primarily lauric acid. Unlike long-chain fats, MCTs are rapidly absorbed and transported directly to the liver, where they are converted into ketones an efficient alternative energy source for the brain [14]. Literature reveals that ketogenic-like metabolic support through MCTs can improve focus and reduce seizure-like activity in some neurodevelopmental disorders [15].

2.5. Gula Saka: A Low Glycemic Index Alternative

"Gula Saka," a traditional palm sugar from the Matur and Lawang areas of West Sumatra, offers a distinct nutritional advantage over refined cane sugar. It possesses a lower Glycemic Index (GI) and contains trace minerals such as potassium, magnesium, and zinc [15]. Maintaining stable blood glucose levels is paramount in ASD management, as rapid spikes in glucose from refined sugars are frequently correlated with hyperactivity and irritability [16].

2.6. Sensory Acceptance and Food Neophobia in ASD

One of the greatest challenges in ASD nutritional therapy is food neophobia the refusal to try new foodscand sensory hypersensitivity. Traditional snacks like *Lapek* provide a "cultural familiarity" that can bypass the resistance often seen with foreign GFCF products [8, 14]. The soft, consistent texture of steamed snacks and the natural aromatic profiles of pandan and coconut are highly compatible with the sensory profiles favored by many children with ASD, increasing the likelihood of long-term dietary compliance [9].

2.7 Sensory Processing and Behavioral Feeding Patterns in ASD

Children with ASD frequently demonstrate atypical sensory processing, which significantly impacts their eating behaviors. According to sensory integration theory, the brain's ability to organize and interpret sensory input is disrupted in ASD, resulting in either hypersensitivity or hyposensitivity to food-related stimuli such as texture, smell, and visual appearance [19]

This sensory dysregulation contributes to feeding difficulties, including strong preferences for specific textures (e.g., soft or crunchy foods) and rejection of mixed or inconsistent textures. Studies have shown that children with ASD prefer foods with predictable sensory properties, as unpredictability may trigger anxiety and refusal behaviors [20]

3. Methodology

3.1. Research Design

This study employed a two-stage research design. The first stage utilized an Experimental Laboratory approach for product development and formulation. The second stage involved a Descriptive Quantitative method to evaluate sensory acceptability through hedonic testing.

3.2. Study Setting and Timeline

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The product development and formulation phase were conducted at the Food Technology Laboratory/Test Kitchen in Bukittinggi, West Sumatra. The sensory evaluation was carried out across several locations in Bukittinggi, specifically targeting Special Needs Schools (SLB) in the Gulai Bancah area and local ASD support communities, ensuring direct access to the target demographic.

3.3. Materials and Instrumentation

- Primary Ingredients: Local purple sweet potato (Agam cultivar), fresh snakehead fish (*Channa striata*) sourced from Pasar Bawah, fresh coconut milk, and traditional palm sugar (*Gula Saka*) from Matur.
- Instrumentation: A food dehydrator was used for the preparation of fish albumin powder. Other essential tools included a digital analytical scale, a standardized steaming apparatus, and sensory evaluation forms (Facial Hedonic Scale).

3.4. Research Procedures
The study was executed through the following sequential phases:
3.4.1.Formulation Phase

A standardized base for the traditional snack (*Lapek*) was modified into three distinct formulations (F1, F2, and F3) with varying ratios of purple sweet potato flour to snakehead fish albumin powder:
F1 (90:10 ratio)
F2 (85:15 ratio)
F3 (80:20 ratio)

These variations were designed to determine the optimal balance between high nutritional density (albumin) and palatable texture.

3.4.2. Nutritional Estimation
A theoretical proximate analysis and laboratory-based estimations were conducted to determine the protein (albumin) concentration and verify the gluten-free status of the final carbohydrate matrix.
3.4.3. Sensory Evaluation (Hedonic Test)

- Panelists: The panel consisted of 15–20 children diagnosed with Autism Spectrum Disorder (ASD), accompanied by their parents/guardians as untrained proxies for communication.
- Attributes: The evaluation focused on four key sensory parameters: Color, Aroma, Taste, and Texture.
- Scaling: Due to the communicative challenges associated with ASD, a 5-point Facial Hedonic Scale (ranging from "Very Sad" to "Very Happy" icons) was utilized. This visual scale facilitated an intuitive response from the children regarding their preference for the innovated *Lapek*.

3.5. Data Analysis
Data collected from the facial hedonic scales were analyzed using Descriptive Statistics to determine mean preference scores. To identify significant differences in preference between the three formulations (F1, F2, and F3), the Friedman Test was employed, followed by a *post-hoc* analysis if a significant p-value (<0.05) was observed.

4. Results and Discussion

4.1. Optimization of the GFCF Lapek Formulation

The physical characteristics of the three formulations (F1, F2, F3) were successfully documented. Table 1 summarizes the physical properties and estimated nutritional profiles.

Table 1. Physical Properties and Nutritional Estimation of Formulated Snacks

Formulation	Ratio (Potato:Fish)	Texture Profile	Color Stability	Albumin Content

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				(Est.)
F1	90 : 10	Soft, elastic, familiar	Vibrant Purple	4.2 g / 100g
F2	85 : 15	Firm, slightly dense	Deep Purple	6.8 g / 100g
F3	80 : 20	Grainy, slightly dry	Dark Purple	8.5 g / 100g

As shown in Table 1, F1 provided the most traditional "Lapek" texture. However, F2 was selected as the optimal therapeutic choice because it offered a significant increase in albumin content (6.8g) without compromising the structural integrity of the snack.

The selection of F2 (85:15) as the optimal formulation aligns with the principle of "nutrient density" without sacrificing physical palatability. While F3 yielded the highest albumin concentration, its grainy texture and slight dryness suggest that a 20% inclusion of fish powder reaches a saturation point where the protein matrix interferes with the starch gelatinization of the sweet potato and tapioca. This interference often results in a "sandy" mouthfeel, which is particularly problematic for ASD children who exhibit tactile defensiveness in oral motor functions [23]. In contrast, F2 maintains a cohesive structure, ensuring that the therapeutic dose of albumin (6.8g) is delivered in a format that resembles the traditional soft-elastic profile of *Lapek*.

4.2. Sensory Acceptability Results

The sensory evaluation using the 5-point Facial Hedonic Scale (n=20) revealed a high acceptance rate among children with ASD in Bukittinggi.

Table 2. Mean Sensory Preference Scores (Facial Hedonic Scale 1-5)

Attribute	F1 (Mean ± SD)	F2 (Mean ± SD)	F3 (Mean ± SD)	p-value*
Color	4.7 ± 0.4	4.6 ± 0.5	4.2 ± 0.8	0.065
Aroma	4.3 ± 0.6	4.2 ± 0.7	3.5 ± 0.9	0.012
Texture	4.5 ± 0.5	4.0 ± 0.6	3.1 ± 0.7	0.008
Taste	4.6 ± 0.4	4.3 ± 0.5	3.4 ± 1.1	0.015

*Friedman Test (significance at $p < 0.05$)

Discussion on Sensory Perception:

The results indicate that Color was the most positively received attribute across all formulations, confirming that the natural purple hue from Agam's sweet potatoes is visually stimulating for ASD children. In contrast, F3 saw a significant drop in Texture and Taste scores. Parents reported that the 20% fish albumin ratio (F3) introduced a slight "aftertaste" and a grainier mouthfeel, which triggered sensory aversion in some participants. F2 emerged as the most balanced formulation, maintaining a high taste score (4.3) while delivering therapeutic levels of albumin.

The significant p-values in Aroma (0.012), Texture (0.008), and Taste (0.015) highlight the sensitivity of the ASD demographic to even minor compositional changes. The high score for Color (4.6–4.7) across formulations confirms that anthocyanin-based pigmentation is not only safe but also visually engaging for children with neurodevelopmental disorders [24]. The decline in Taste for F3 can be attributed to the "metallic" notes often associated with concentrated fish peptides. However, the consistent acceptance of F1 and F2 proves that traditional Indonesian culinary techniques—specifically steaming in banana leaves provide a natural "aroma-therapy" effect that increases food interest and reduces neophobia [25].

The observed preference patterns can also be explained through sensory processing theory. The high acceptance of color and texture in F1 and F2 formulations indicates that children with ASD respond positively to visually simple and texturally predictable foods. This aligns with previous findings that consistent sensory input reduces anxiety and increases willingness to consume food [26].

Conversely, the lower acceptance of F3 highlights the role of oral sensory defensiveness, where even minor changes in texture (e.g., graininess) can trigger rejection responses. This phenomenon is well-documented in ASD feeding behavior literature, where tactile sensitivity in the oral cavity significantly influences dietary acceptance [5].

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4.3. The Synergistic Effect of Indigenous Ingredients

The success of the formulation in Bukittinggi is attributed to the "Masking Effect" of West Sumatran ingredients. The high fat content in local coconut milk and the distinct mineral-rich sweetness of Gula Saka effectively neutralized the metallic/fishy odor of the *Channa striata* extract. From a nutritional standpoint, this synergy is crucial; the medium-chain triglycerides (MCTs) in coconut milk act as a carrier for the anthocyanins, potentially enhancing their bioavailability across the blood-brain barrier [27].
Beyond flavor masking, the synergy in the *Lapek* formulation facilitates a "lipid-based delivery system" for bioactive compounds. The Medium-Chain Triglycerides (MCTs) in West Sumatran coconut milk do not only mask fishy odors but also act as a crucial solvent that enhances the stability of anthocyanins during digestion [28]. Recent literature suggests that MCT-rich diets may provide neuroprotective benefits by increasing ketone production, which serves as a more efficient fuel for the ASD brain under oxidative stress [29]. Furthermore, the trace minerals in Gula Saka (magnesium and zinc) act as essential co-factors for the neurotransmitter synthesis often disrupted in ASD, making this "re-invented" snack a multi-modal therapeutic tool rather than a mere calorie source.

4.4. Cultural Acceptance and Economic Sustainability

Unlike imported GFCF products (e.g., almond-based biscuits), the re-innovated *Lapek* utilized familiar flavors. During the trials in Gulai Bancah, caregivers noted that children were less hesitant to try the snack because it smelled like "home food." Economically, the cost-per-serving was estimated to be 65% lower than commercial GFCF alternatives available in Indonesian pharmacies, making it a highly sustainable strategy for long-term dietary intervention [30].
The 65% cost reduction achieved by using Bukittinggi's local biodiversity is a critical finding for public health scalability. In many developing nations, the "GFCF-premium" the higher cost of specialized allergy-friendly foods often leads to total dietary failure within the first three months [30]. By utilizing indigenous crops like purple sweet potatoes from Agam, the intervention becomes "economically resilient." Moreover, the use of *Lapek* as a vehicle for therapy fosters "Social Inclusion"; when an ASD child eats a snack that looks and smells like what their peers are eating, it reduces the stigma and social isolation often associated with restrictive clinical diets [31].

5. Conclusion

This study demonstrates that reinventing West Sumatran traditional snacks using local biodiversity—specifically purple sweet potato, snakehead fish, and Gula Saka is a viable strategy for ASD nutritional therapy. The F2 formulation (85:15) provides an optimal balance of high-albumin content and sensory acceptability. By utilizing indigenous ingredients, Bukittinggi can lead a model for sustainable, culturally-centered dietary interventions that reduce dependence on expensive imported GFCF products.

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