

# Sensory Evaluation of Bread Formulated with Jackfruit (*Artocarpus heterophyllus*) Flour at Varying Substitution Levels

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## ABSTRACT

**Background:** The increasing demand for low-gluten bakery products has led to growing interest in the use of jackfruit (*Artocarpus heterophyllus*) flour as a functional ingredient in bread formulation. This study investigates the sensory properties of bread produced with varying levels of jackfruit flour substitution (0%, 20%, and 40%) to evaluate its suitability as a partial wheat flour replacement. **Methods:** Jackfruit flour was produced through cleaning, slicing, oven-drying, grinding, and sieving of unripe jackfruit, followed by incorporation into bread dough using standardized ingredient proportions and baking conditions. Sensory evaluation was conducted with 30 untrained panelists who assessed appearance, aroma, texture, taste, and overall acceptability using a 9-point hedonic scale. Data were analyzed using descriptive statistics and one-way ANOVA. **Results:** Results showed that partial substitution with 20% jackfruit flour produced bread with acceptable sensory scores comparable to the control, while 40% substitution resulted in significantly lower scores for appearance, texture, and overall acceptability ( $p < 0.05$ ). **Conclusion:** The findings suggest that jackfruit flour can be incorporated up to 20% without compromising sensory quality, offering a promising approach for developing low-gluten, fibre-enriched bread. Further research incorporating instrumental analysis is recommended to complement sensory evaluation.

## Keywords:

Jackfruit Flour; Functional Bread; Gluten-Reduced Bread; Sensory Evaluation; Consumer Acceptability

## INTRODUCTION

Bread is one of the most widely consumed staple foods globally and serves as a major source of carbohydrates, protein, and dietary energy. Traditional bread relies primarily on wheat flour, which contains gluten; a structural protein essential for dough elasticity and gas retention. However, the increasing prevalence of gluten-related disorders and consumer demand for healthier alternatives have driven research on gluten-reduced and functional bakery products (Lebwohl et al., 2023; Melini & Melini, 2021). Recent dietary trends also highlight the need for low-glycaemic bakery formulations to support individuals managing diabetes and metabolic syndrome (Ferrari et al., 2022).

Jackfruit (*Artocarpus heterophyllus*) flour has gained scientific interest as a functional ingredient due to its favourable nutritional properties. Made from unripe jackfruit, the flour is rich in dietary fibre, resistant starch, and bioactive compounds, while naturally free of gluten (Kumar et al., 2023; Shilpa & Lakshmi, 2021). Studies have demonstrated its potential for improving fibre content, lowering glycaemic response, and enhancing mineral availability when incorporated into bakery and snack products (Reddy et al., 2022; Shelar et al., 2023).

As an underutilised tropical crop, jackfruit also offers sustainability advantages by reducing food waste and promoting plant-based food diversification.

Despite these benefits, substituting wheat flour with jackfruit flour can influence critical sensory attributes such as texture, appearance, flavour, and aroma—factors that strongly determine consumer acceptance in bakery products (Costa et al., 2023). Previous research reports that gluten dilution and the high fibre content of jackfruit flour may affect dough handling, crumb structure, and flavour profile. However, most existing studies emphasize nutritional and functional properties rather than comprehensive sensory evaluation of jackfruit-based bread.

Therefore, this study aims to evaluate the sensory acceptability of bread formulated with jackfruit flour at substitution levels of 0%, 20%, and 40%, focusing on appearance, aroma, texture, taste, and overall acceptability using a hedonic scale. By identifying the substitution threshold that maintains desirable sensory qualities, this study provides insights for the formulation of nutritionally enhanced, gluten-reduced bread using jackfruit flour as a sustainable functional ingredient.

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## MATERIALS AND METHODS

### Research Design

A laboratory-based experimental design was employed to examine the sensory properties of bread made with different ratios of jackfruit flour and wheat flour. All procedures—including flour preparation, ingredient blending, dough development, and baking—were standardised to ensure that differences in sensory evaluation could be attributed solely to substitution levels.

### Raw Materials Preparation

Fresh unripe jackfruit, commercial wheat flour, yeast, sugar, vegetable oil, and salt were sourced from local markets. All ingredients were inspected for quality and stored under appropriate conditions to prevent contamination or moisture absorption before use.

### Jackfruit Flour Production

Unripe jackfruit was cleaned, peeled, and chopped into small pieces (Figure 1).



**Figure 1:** Chopped jackfruit pieces prepared for drying

The pieces were arranged in a single layer and oven-dried at 60°C for 12 hours to reduce moisture content. Dried slices were ground using an electric grinder, followed by sieving through a <math><250\ \mu\text{m}</math> mesh to obtain fine, uniform flour appropriate for bakery applications (Figure 2). The flour was stored in airtight containers until used.



**Figure 2:** Grinding of dried jackfruit slices into flour

### Preparation of Ingredient Blends

Three flour formulations were prepared:

- Control (0%): 100% wheat flour (Sample 1)
- 20% substitution: 80% wheat flour + 20% jackfruit flour (Sample 2)
- 40% substitution: 60% wheat flour + 40% jackfruit flour (Sample 3)

All formulations were measured by weight using digital scales to ensure accuracy and consistency.

### Bread Production

Bread dough was prepared using the following standard recipe for all samples, which were (i) 3 cups flour blend, (ii) 1 cup warm water, (iii) 2 tablespoons white sugar, (iv) 1.5 teaspoons instant yeast, and (v) 1 teaspoon salt. Ingredients were mixed until homogeneous, then proofed under identical temperature and humidity conditions. Dough samples were baked in an automatic bread maker at 180°C for 25 minutes to ensure uniform development of crust and crumb across all formulations. After baking, bread samples were cooled to room temperature and stored individually in coded resealable bags to prevent bias during sensory evaluation (Figure 3).



**Figure 3:** Cross-section of jackfruit bread formulated with 20% jackfruit flour substitution, showing crumb texture and colour

### Experimental Variables

The experimental design incorporated both independent and dependent variables. The independent variable was the level of jackfruit flour substitution, which consisted of three formulation levels: 0%, 20%, and 40%. The dependent variables were the sensory attributes evaluated by the panelists, namely appearance, aroma, texture, and taste, along with the overall acceptability score. All sensory responses were obtained through a structured evaluation method to ensure consistency, reliability, and comparability of the data across all bread formulations.

### Data Collection

Sensory evaluation was conducted with 30 untrained panelists from IIUM Kuantan (aged 20–30 years). Inclusion criteria included non-smokers, no known food allergies, and no reported taste or olfactory impairments. Bread samples were coded using random three-digit numbers and presented in randomised order to minimise

psychological and positional bias.

Panelists assessed appearance, aroma, texture, taste, and overall acceptability using a 9-point hedonic scale ranging from “1 = Dislike extremely” to “9 = Like extremely.” All evaluations were performed under controlled laboratory lighting and room temperature.

### Statistical Analysis

All data were analysed using SPSS Version 26. Means  $\pm$  standard deviation (SD) were calculated for each sensory attribute. Differences between bread formulations were tested using one-way ANOVA followed by Bonferroni post hoc tests where applicable. Statistical significance was set at  $p < 0.05$ . Mean sensory scores were compared to determine the most acceptable jackfruit flour substitution level. Emphasis was placed on identifying whether 20% or 40% substitution maintained acceptable sensory quality relative to the control.

## RESULTS AND DISCUSSION

### Statistical Analysis of Sensory Evaluation

The sensory evaluation results for appearance, aroma, texture, taste, and overall acceptability were analysed using one-way ANOVA. Significant differences were detected among the three bread formulations ( $p < 0.05$ ), demonstrating that the level of jackfruit flour substitution influenced the sensory attributes assessed by the panel. The mean scores for each sensory parameter are presented in Table 1.

**Table 1:** The Mean Scores of Sensory Characteristics Between Samples

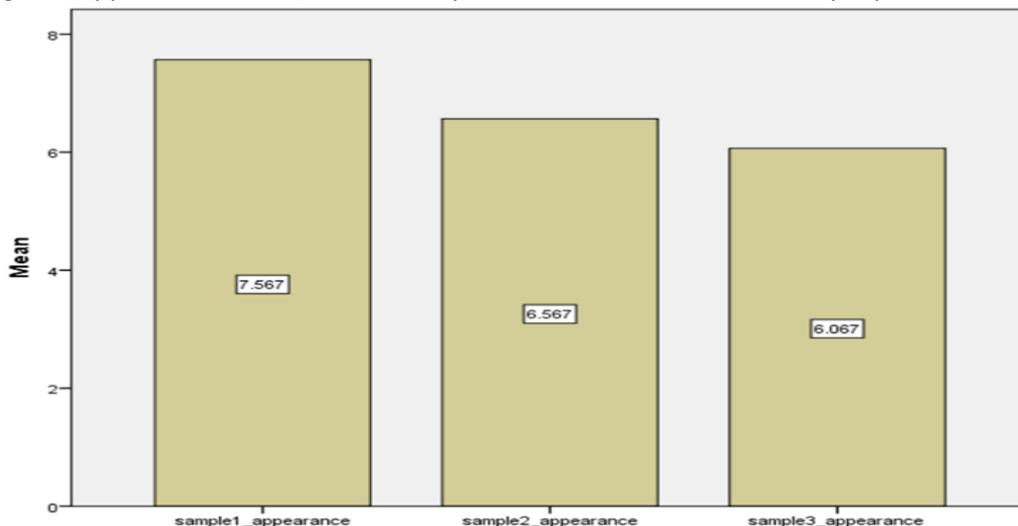
Sensory Characteristics	N	S1 (Mean $\pm$ SD)	S2 (Mean $\pm$ SD)	S3 (Mean $\pm$ SD)	p-value	Significance Level
Appearance	30	7.57 $\pm$ 1.46	6.57 $\pm$ 1.61	6.07 $\pm$ 1.79	p = 0.00	S
Aroma	30	7.50 $\pm$ 1.38	6.67 $\pm$ 1.66	5.97 $\pm$ 1.63	p = 0.00	S
Texture	30	7.63 $\pm$ 1.37	5.43 $\pm$ 1.87	4.83 $\pm$ 1.91	p = 0.00	S
Taste	30	7.70 $\pm$ 1.44	4.90 $\pm$ 1.90	4.47 $\pm$ 1.91	p = 0.00	S
Overall Acceptance	30	7.70 $\pm$ 1.37	5.60 $\pm$ 1.71	4.87 $\pm$ 1.78	p = 0.00	S

**Note:** S = Significant ( $p < 0.05$ )

### Appearance of Jackfruit Bread

Appearance refers to visual qualities such as colour, shape, and crumb structure. The results showed significant differences among the three samples ( $p = 0.00$ ), with the control sample (100% wheat flour) receiving the highest appearance score, followed by

20% jackfruit flour, while 40% substitution scored the lowest (Figure 4). Higher substitution levels led to a darker crumb and less uniform loaf volume. This is consistent with findings in fibre-enriched breads, where gluten dilution reduces gas retention and browning uniformity. Post hoc analysis (Bonferroni) confirmed that all sample pairs differed significantly.



**Figure 4:** Mean appearance scores of jackfruit bread for the three sample formulations

The study shows that higher substitution levels resulted in darker crumb and less desirable loaf structure due to decreased gluten availability and increased fibre content.

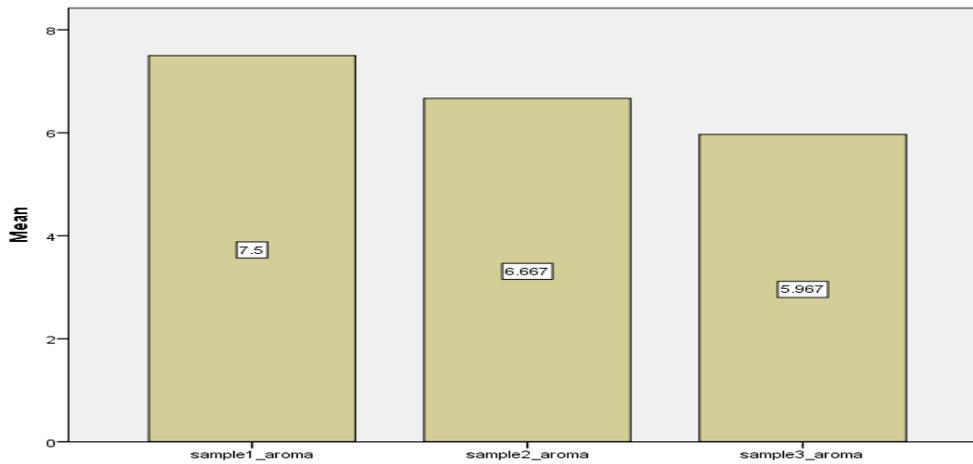
This aligns with studies that show non-gluten flours reduce gas retention in doughs (Cappelli et al. 2020) and others that highlight how increased dietary fibre promotes intensified Maillard reaction browning in high-fibre bread products (El Hosry 2025; Schütte 2024).

received the lowest score, likely due to the stronger natural aroma of jackfruit flour (Figure 5).

Research indicates that jackfruit flour contains distinct volatile esters that may overpower typical bread aroma at higher substitution levels. Post hoc results showed all samples differed significantly from one another.

### Aroma of Jackfruit Bread

Aroma is influenced by volatile compounds released during baking. ANOVA showed significant differences ( $p = 0.00$ ). The control sample had the highest aroma score, followed by 20% jackfruit flour. The 40% sample



**Figure 5:** Mean aroma scores of jackfruit bread for the three sample formulations

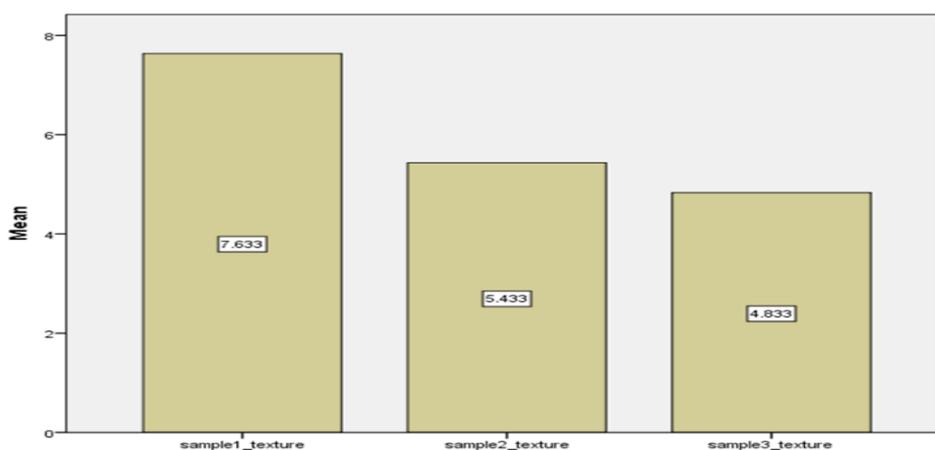
Jackfruit’s natural volatile compounds produced a stronger, fruit-like aroma in the bread, which became particularly pronounced at the 40% substitution level. This is consistent with findings in recent literature, which report that tropical fruit-based flours contribute distinct aromatic profiles due to their ester, aldehyde, and ketone compounds. However, these intensified aromas may not always align with consumer expectations for conventional wheat bread, making them less acceptable at higher substitution levels (Bharath et al., 2023; Nunes et al., 2024).

#### Texture of Jackfruit Bread

Texture is one of the most critical sensory attributes, encompassing softness, chewiness, and mouthfeel. Significant differences were found across samples ( $p = 0.00$ ). The control sample scored the highest, followed by

20% substitution, while 40% substitution had the lowest score (Figure 6). This trend is expected because jackfruit flour contains no gluten. Increasing the flour ratio reduces dough elasticity, loaf volume, and crumb softness—common characteristics of gluten-reduced bread. Post hoc results confirmed all samples were significantly different.

The reduction in texture scores is closely linked to the absence of gluten in jackfruit flour. As substitution levels increase, the dough loses its ability to form a cohesive gluten network, resulting in reduced elasticity, increased firmness, and a denser crumb structure. These textural changes are widely reported in current gluten-free and composite-flour bread research, which consistently shows that non-gluten flours weaken gas retention, limit dough expansion, and produce tighter crumb formations (Cappelli et al., 2020; Sciarini et al., 2024).



**Figure 6:** Mean texture scores of jackfruit bread for the three sample Formulations Taste of Jackfruit Bread

Taste significantly decreased with higher substitution ( $p = 0.00$ ). The familiar wheat-based flavour in the control sample was preferred. The 20% jackfruit bread remained

acceptable, while 40% substitution was least preferred (Figure 7). Higher jackfruit flour content introduces a stronger fruit-based flavour, which some panelists

described as unfamiliar in bread. All sample differences were statistically significant based on Bonferroni tests.

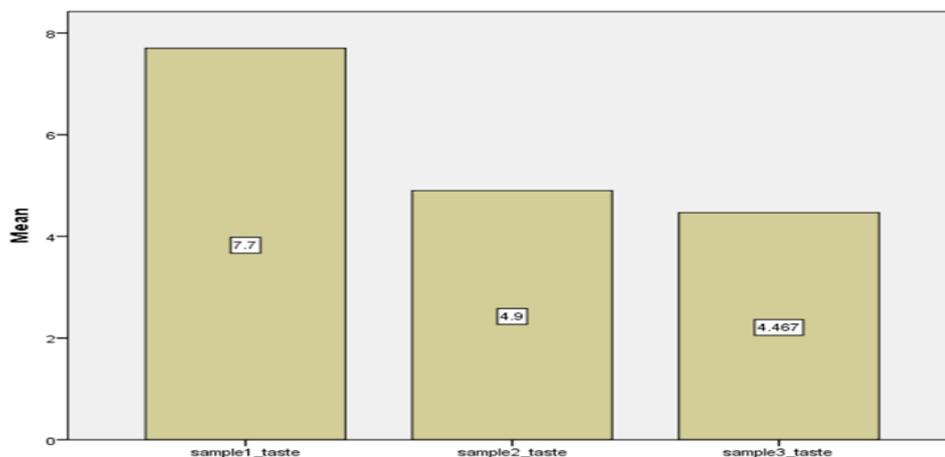


Figure 7: Mean taste scores of jackfruit bread for the three sample formulations

Taste remained acceptable at the 20% substitution level but declined sharply at 40%, indicating a sensory threshold at which jackfruit flour begins to dominate the flavour profile. At higher levels, the naturally sweet, fruity, and slightly musky notes of jackfruit become more pronounced, altering the expected taste of conventional bread. Similar findings have been reported in recent studies, which show that fruit-based and high-fibre flours can introduce strong characteristic flavours that may reduce consumer acceptance when added beyond moderate substitution levels (Santos et al., 2023; Devi et al., 2024).

#### Overall Acceptance of Jackfruit Bread

Overall acceptance integrates all sensory attributes. Consistent with previous results, the control sample had the highest score, followed by 20% substitution, and finally 40% substitution (Figure 8). This indicates that up to 20% jackfruit flour can be incorporated while maintaining acceptable consumer preference across attributes. Post hoc analysis confirmed significant differences among all sample comparisons.

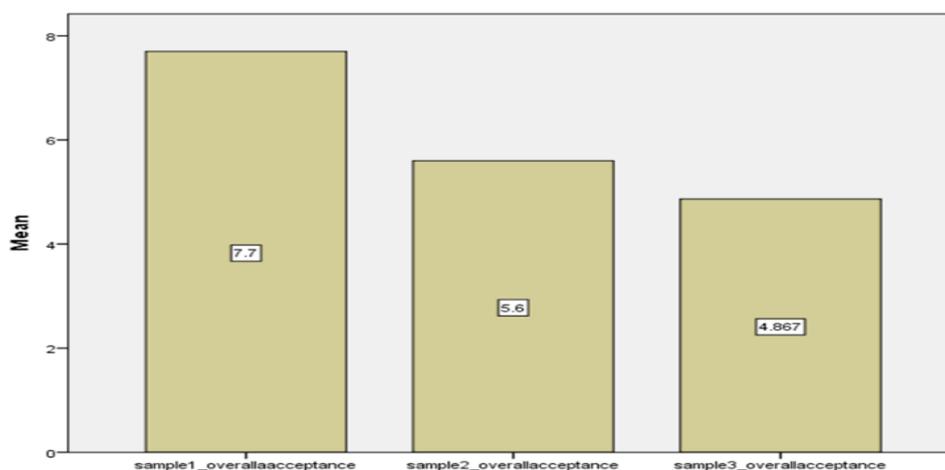


Figure 8: Mean overall acceptance scores of jackfruit bread for the three sample formulations

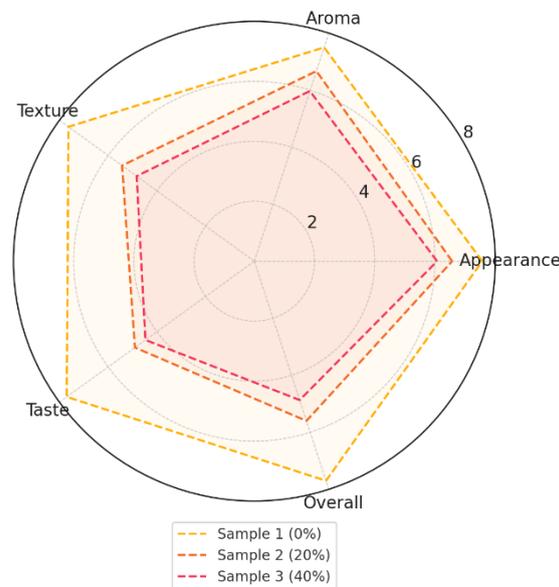
Overall acceptability indicates that 20% jackfruit flour is the optimal substitution level, as it enhances the bread's nutritional value while maintaining acceptable sensory quality. At this level, the product retains desirable characteristics in appearance, aroma, texture, and taste,

without introducing dominant flavours or structural changes that negatively affect consumer preference. In contrast, the 40% substitution level shows a marked decline in acceptability, as the negative effects on texture, aroma, and taste outweigh the potential nutritional

benefits. These findings are consistent with recent studies reporting that moderate incorporation of fruit-based or high-fibre flours can be well tolerated in baked products, but higher levels are often disliked due to stronger flavours and compromised crumb structure (Khan et al., 2023; Velásquez et al., 2024).

### Comparative Sensory Profile

A combined radar chart was generated for visual comparison. The radar chart illustrates the mean sensory scores for appearance, aroma, texture, taste, and overall acceptability for the three jackfruit bread samples. The results show a clear decline in sensory acceptance as the level of jackfruit flour substitution increases (Figure 9).



**Figure 9:** Radar chart of the mean sensory scores for the three jackfruit bread samples

Sample 1 (0% jackfruit flour) recorded the highest scores across all attributes, indicating that the control bread was the most preferred by the panelists. Sample 2 (20% substitution) showed moderate scores, suggesting that partial replacement of wheat flour with jackfruit flour is still acceptable in terms of sensory quality. Sample 3 (40% substitution) received the lowest ratings for all parameters, indicating that a higher proportion of jackfruit flour negatively affected the bread's texture, taste, and overall acceptability. Overall, the chart demonstrates that while small amounts of jackfruit flour can be used without major sensory drawbacks, higher substitution levels reduce consumer acceptance of the bread. It shows a gradual decline across all attributes as substitution increases. The 20% sample demonstrates a moderate reduction from the control but remains within an acceptable sensory threshold.

### CONCLUSION

This study examined the effects of substituting wheat flour with jackfruit (*Artocarpus heterophyllus*) flour at 20% and 40% levels on the sensory properties of bread. The results demonstrated that jackfruit flour significantly influenced appearance, aroma, texture, taste, and overall

acceptability across all substitution levels. Bread made with 20% jackfruit flour maintained acceptable sensory quality and scored moderately across all evaluated attributes, indicating that this level of substitution offers a viable balance between nutritional enhancement and consumer preference.

In contrast, the 40% substitution level led to substantial declines in sensory acceptance, particularly in texture and taste, largely due to gluten dilution, increased crumb density, and stronger jackfruit-derived flavour and aroma. These findings suggest that while jackfruit flour provides nutritional advantages such as higher dietary fibre and lower glycaemic potential, its use in bread should be limited to moderate levels to preserve sensory appeal.

Overall, this study supports the incorporation of jackfruit flour as a functional ingredient in bakery applications, especially at substitution levels up to 20%. Future research is recommended to explore textural optimisation techniques, enzymatic improvers, hydrocolloid incorporation, and instrumental analyses to enhance product quality and broaden the commercial feasibility of jackfruit-based functional bread.

### ACKNOWLEDGEMENT

This research was not funded by any grant.

#### Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

During the preparation of this work, the author(s) used ChatGPT 5.1 to draft text and format citations. The author(s) subsequently reviewed, revised, and approved all content, and accept full responsibility for the final manuscript.

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