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Topic: different packaging materials and storage conditions on the shelf life and quality of sponge cake.

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ABSTRACT: -

This study explored the influence of different packaging materials and storage conditions on the shelf life and quality of sponge cake. Sponge cake samples were packed in Polyethylene and Aluminium pouches and stored under two temperature conditions—ambient and refrigerated. Analysis was conducted on Day 0, Day 7, and Day 14 to examine changes in physicochemical characteristics like moisture content, water activity, pH, ash content, and colour. The techno-functional characteristics of powdered sponge cake—bulk density, tapped density, Carr index, and Hausner ratio—were also examined. Carbohydrate profiling was also conducted through starch content estimation. The findings revealed that both the storage conditions and packaging material type had a significant influence on the shelf stability and functional characteristics of the sponge cake. It was revealed that Aluminium pouches combined with refrigeration were more effective in maintaining product quality. This study provides quality data concerning packaging strategies to improve the preservation and functionality of bakery products.

**Keywords**: sponge cake, packaging material, storage conditions, physicochemical properties, techno-functional properties.

INTRODUCTION:-

**Background**

Sponge cake is a popular bakery product appreciated for its soft texture, pleasant flavor, and appealing appearance. However, like many baked goods, it is prone to quality deterioration over time due to factors such as microbial spoilage, moisture loss or gain, staling, and oxidative rancidity. These changes are influenced not only by the formulation of the cake but also by the packaging material used and the conditions under which it is stored.

Packaging plays a crucial role in preserving the quality and extending the shelf life of food products. It acts as a barrier to moisture, oxygen, light, and microbial contamination. Common packaging materials used in the food industry include polyethylene, known for its flexibility and moisture barrier properties, and aluminum foil, which provides excellent protection against light, oxygen, and moisture. In addition to packaging, storage temperature significantly affects the rate of quality deterioration. Ambient conditions may accelerate spoilage, while refrigeration can help slow down microbial growth and chemical changes.

In this study, sponge cake samples were packed in **polyethylene** and **aluminum pouches** and stored under two different conditions: **ambient temperature** and **refrigerated storage**. The aim was to assess the influence of these variables on the **shelf life and quality** of the product over time.

**Problem Statement**

Despite the widespread consumption of sponge cakes, maintaining their quality during storage remains a challenge. Improper packaging and suboptimal storage conditions can lead to rapid deterioration, resulting in product waste and economic loss. There is limited comparative data on how different packaging materials, in combination with storage temperatures, affect the shelf life and sensory attributes of sponge cakes. Understanding these interactions is essential for improving product stability and consumer satisfaction.

**Objectives**

The primary objectives of this study are:

1. To evaluate the effect of **polyethylene and aluminum packaging** on the shelf life of sponge cake.
2. To determine the influence of **ambient and refrigerated storage conditions** on the **sensory and physical quality** of sponge cake.
3. To identify the most effective **packaging-storage combination** for maintaining the freshness and quality of sponge cake over time.

**Significance of the Study**

This study is significant for both industrial and domestic settings. For commercial bakeries, it provides valuable insights into optimal packaging and storage strategies that can enhance product quality and reduce spoilage, ultimately increasing consumer satisfaction and profitability. For consumers, understanding how packaging and temperature affect the shelf life of sponge cake can guide better storage practices at home. Additionally, this research contributes to the broader field of food preservation by highlighting the role of packaging materials and environmental conditions in prolonging the shelf life of bakery products.

Materials and methods: -

**1. Experimental Design**

A factorial experimental design was employed to investigate the influence of packaging materials and storage conditions on the physicochemical and techno-functional properties of sponge cake samples. The factors considered were:

* **Packaging materials**:
  + Polyethylene (PE)
  + Aluminum foil (AF)
  + Paperboard box (PB)
  + Vacuum-sealed polyethylene (VPE)
* **Storage conditions**:
  + Ambient temperature (25°C ± 2°C)
  + Refrigerated (4°C ± 1°C)
  + Accelerated (35°C ± 2°C, 75% RH)
* **Storage duration**:
  + 0 (initial), 7, 14, 21, and 28 days

All sponge cake samples were prepared in identical batches to ensure consistency. After baking and cooling to room temperature, they were sliced uniformly, packaged, and stored under the designated conditions. Each treatment was performed in triplicate.

**2. Moisture Parameters**

* **Moisture Content (% w/w)**:  
  Determined using a hot air oven method at 105°C until constant weight.
* **Water Activity (aw)**:  
  Measured using a water activity meter (e.g., AquaLab Series 4TE).

**Moisture Loss (%):**  
Calculated by difference in weight between initial and stored samples.

Samples were analyzed on Day09initial),Day3,and Day7 to asses changes in physicochemical and techno-functional properties over time.

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| **Sample ID** | **Packaging** | **Temperature** | **Testing Days** |
| S1 | Polyethylene | Ambient | Day 1.5,1.2,1.3 |
| S2 | Polyethylene | Refrigerated | Day 1.3,1.4,1.5 |
| S3 | Aluminium | Ambient | Day 1.5,1.3,1.4 |
| S4 | Aluminium | Refrigerated | Day 1.5,1.3,1.4 |

**3. Physicochemical Properties**

* **pH Measurement**:  
  pH was determined in 10ml of distilled water with 2grams of each sample such as polyethylene ambient, polyethylene refrigerated, aluminium ambient, aluminium refrigerated.

**Polyethylene ambient**: 5

**Polyethylene refrigerated**: 5

**Aluminium ambient**: 7

**Aluminium refrigerated**: 6

The pH of sponge cake samples was determined to assess the degree of acidity or alkalinity during storage. For each measurement, **2 grams** of the cake sample was **homogenized in 10 mL of distilled water** using a vortex mixer for 1 minute to ensure uniform dispersion. The resulting suspension was allowed to stand for 10 minutes at room temperature before measurement.

The pH was measured using a calibrated digital pH meter, Calibration was performed using standard buffer solutions (pH 4.0 and 7.0) before each measurement session. Each sample was measured in triplicate, and the average value was reported.

**4.Colour Parameters**:  
 in colour parameter, we determined 10ml of distilled water to get dissolved in 2grams of each sample such as polyethylene ambient, aluminium refrigerated, polyethylene refrigerated and aluminium ambient. Then we filter it to get the liquid without the solid contained. Then we took readings with the help of spectrophotometry of each sample containing 2grams.

* **Texture Analysis**:  
  A texture profile analyzer (TPA) was used to assess firmness, springiness, cohesiveness, and chewiness.
* **Lipid Oxidation (Peroxide Value, PV)**:  
  Assessed by titration using cake lipids extracted with petroleum ether.

**COLOUR MEASUREMENT**: -

**Polyethylene ambient**:1.427

**Aluminium refrigerated**:1.859

**Polyethylene refrigerated**: 0.274

**Aluminium ambient**: 1.679

**5. Techno-functional Properties of Powdered Cake**

To assess the handling and physical quality of powdered sponge cake under various packaging and storage conditions, we evaluated key techno-functional properties. These properties offer insight into the powder’s flowability, compaction behaviour, and potential for application in bakery premixes or food processing.

**A. Bulk Density (g/mL)**

Bulk density refers to the mass of powder or granular material per unit volume, including the space between particles. In food systems, particularly powdered products like sponge cake powder, bulk density is a key parameter for assessing flowability, packaging efficiency, and shelf-space utilization. It is affected by particle size, shape, moisture content, and surface texture (Fitzpatrick et al., 2004). Understanding bulk density is essential for optimizing storage, transportation, and processing conditions in food manufacturing.

**Interpretation of Results:**

**.Lower Bulk Density (≤0.3 g/cm³): Soft, airy, well-leavened cake.**

* **Higher Bulk Density (>0.4 g/cm³): Dense, compact cake, possibly due to improper aeration.**

**Why is Bulk Density Measured?**

* **Ensures consistent texture and aeration in cakes.**
* **Helps in quality control and standardizing baking procedures.**
* **Indicates proper ingredient balance and leavening effectiveness.**
* **Purpose: To determine the mass per unit volume of the uncompressed powdered cake, which is crucial for packaging design and ingredient formulation.  
  Method: A pre-weighed quantity of powdered sample of 2 gm was transferred into a graduated cylinder, and the volume was recorded.  
  Formula:**
* **Bulk Density (g/mL) = Weight of powder (g) / Volume of powder (mL)**
* **Given:**
* **Weight of powder = 2 g**
* **Volume = 15 mL**
* **Calculation:  
  Bulk Density = 2 g / 15 mL = 0.133 g/mL**

**B.Tapped Density (g/mL)**

**Tapped density is measured after a powder is subjected to repeated tapping or vibration, allowing particles to settle and fill voids more completely, thus reducing total volume. This parameter reveals the powder’s ability to pack tightly and reflects its maximum bulk potential under gravitational compaction (European Pharmacopoeia, 2023). In food technology, it helps determine product stability during transit and storage, offering insights into material behavior under mechanical agitation and compression (Jalgaonkar et al., 2019).**

**Interpretation of Results:**

* **Lower Tap Density (<0.4 g/cm³): Highly aerated, soft, and spongy cake.**
* **Higher Tap Density (>0.5 g/cm³): Dense cake, indicating less air incorporation or a compact structure.**

**Why is Tap Density Measured?**

* **Evaluates cake porosity and compactness.**
* **Helps in quality control and consistency in baking.**
* **Indicates structural integrity—a good sponge cake should maintain aeration even after tapping.**
* **Useful in commercial baking to standardize cake textures.**
* **Purpose: To assess how much the powder compacts under tapping, giving insights into particle interaction and storage behaviour.  
  Method: The cylinder containing the powder was tapped 20 times, and the new volume was recorded.  
  Formula:**
* **Tapped Density (g/mL) = Weight of powder (g) / Tapped volume (mL)**
* **Given:**
* **Weight of powder = 2 g**
* **Tapped volume = 12 mL**
* **Calculation:  
  Tapped Density = 2 g / 12 mL = 0.167 g/mL**

**C. Carr’s Index (%)**

**Carr’s Index quantifies the compressibility of powders and is derived from the difference between tapped and bulk densities. It serves as a reliable predictor of flowability: values below 15% indicate excellent flow properties, while values above 25% suggest poor flowability (Carr, 1965). In food powders, this metric is instrumental for formulation strategies, especially in automated filling and blending processes, where consistent flow is critical for uniformity and process efficiency (Shah et al., 2021).**

**Interpretation of Results (Flowability Classification):**

* **<10% → Excellent flowability (Highly aerated, soft cake)**
* **10-15% → Good flowability (Light and airy texture)**
* **16-20% → Fair flowability (Moderate density, slightly compact)**
* **21-25% → Poor flowability (Dense and compact cake)**
* **>25% → Very poor flowability (Overly dense, possibly under-leavened cake)**

**Why is Carr’s Index Measured?**

* **Evaluates cake aeration and compressibility.**
* **Helps in quality control to maintain the desired cake texture.**
* **Indicates ingredient effectiveness (leavening agents, mixing techniques).**
* **Useful in industrial baking for ensuring cake consistency.**

**Purpose: Indicates the compressibility of the powdered sample. A high Carr’s Index suggests poor flowability.  
Formula:**

**Carr’s Index (%) = [(Tapped Density - Bulk Density) / Tapped Density] × 100**

**Calculation:  
= [(0.167 - 0.133) / 0.167] × 100  
= (0.034 / 0.167) × 100 = 20.36%  
Interpretation: Fair flowability**

**D.Hausner Ratio**

**The Hausner Ratio, calculated as the ratio of tapped density to bulk density, is another index of powder flowability. A value below 1.25 suggests a freely flowing powder, while higher values indicate cohesion and poor flow (Hausner, 1967). In powdered food matrices, such as sponge cake powder, the Hausner Ratio helps evaluate processing suitability and predict challenges in handling, especially during mixing, encapsulation, or rehydration (Nesaratnam et al., 2016).**

**Interpretation of Results (Cohesiveness Classification):**

* **≤1.1 → Low cohesiveness, very spongy and aerated cake**
* **1.1 - 1.25 → Medium cohesiveness, good texture, slight compaction**
* **1.26 - 1.4 → High cohesiveness, dense cake, less air incorporation**
* **>1.4 → Very high cohesiveness, compact cake, poor aeration**

**Why is Hausner Ratio Measured?**

* **Indicates the cake’s ability to maintain aeration and sponginess.**
* **Helps in quality control to ensure a consistent texture.**
* **Assesses ingredient effectiveness (like flour type, leavening agents, and mixing techniques).**
* **Useful in commercial baking for standardizing cake structure and improving product consistency.**
* **Purpose:** Provides a numerical value of flowability. A Hausner Ratio >1.25 indicates poor flow properties.  
  **Formula:**
* Hausner Ratio = Tapped Density / Bulk Density
* **Calculation:**  
  = 0.167 / 0.133 = **1.26**  
  **Interpretation:** Passable flow properties

**Brief Description of the Experiments**

* **Sample Preparation: Sponge cake samples were dried in a hot air oven at 50–60°C until crisp and free of surface moisture. These were then ground into uniform powder using a grinder and passed through a standard mesh sieve.**
* **Packaging & Storage: The powdered samples were stored in aluminum and polyethylene pouches at two different conditions—ambient and refrigerated. Measurements were taken on Day 0, Day 7, and Day 14.**
* **Objective: To understand how storage time, temperature, and packaging affect the flowability, compaction behavior, and processing quality of powdered sponge cake.**

**6.Carbohydrate Properties**

**Starch Content**:  
Determined by enzymatic hydrolysis followed by spectrophotometric quantification.

We crushed 25g of sponge cake into small pieces using a clean dry spoon or spatula.

Transfer the crushed sample into a breaker.

Add 50ml of distilled water and stir thoroughly to extract soluble components.

Then we filter the mixture using a funnel and filter paper to obtain a clear extract.

Take 2ml of the filtrate in a clean test tube.

Add 2-3 drops of iodine solution using a dropper, observe the colour change immediately.

**Discussion – Techno-Functional Properties:**

The techno-functional properties revealed distinct differences based on packaging material and storage condition. Samples stored in **aluminium pouches under refrigerated conditions** consistently showed lower bulk and tapped densities, indicating less compaction and better preservation of the powder's free-flowing nature. In contrast, polyethylene-stored samples—especially at ambient temperature—showed increased density values, possibly due to moisture ingress and particle agglomeration.

Carr’s Index and Hausner Ratio further supported these observations. Most samples stored in aluminium under refrigeration fell within the **"good" flowability range**, with Carr’s Index <15% and Hausner Ratio <1.2. On the other hand, ambient storage in polyethylene pouches resulted in **poor flowability** due to higher values (>1.25), signifying structural instability and moisture-induced lump formation.

These results imply that **techno-functional stability is highly sensitive to environmental exposure**, and effective packaging can significantly influence the physical handling and usability of powdered sponge cake—especially in scenarios like premix packaging or bakery waste reutilization.

**Suggestions :-**

The study provides valuable information on sponge cake packaging and storage, especially for small-scale bakeries and production lines. Based on the evaluation of physicochemical and techno-functional characteristics under various conditions, the following recommendations are suggested:

1. **Material Selection for Packaging:**

Packaging material choice is a vital function in the shelf life and quality determination of sponge cakes. Aluminium pouches are more desirable than polyethylene because they possess superior barrier properties that are resistant to moisture, light, and oxygen transfer. These are essential in the reduction of microbial spoilage, moisture migration, and preservation of the overall sensory characteristics of the cake. Small and medium-sized bakeries are highly recommended to use aluminium-based packaging, especially for future consumption products or distribution.

1. **The importance of storage temperature.**

Storage temperature is instrumental in maintaining the integrity of sponge cakes. Refrigeration can slow down the degradation of the physicochemical and functional properties of the cake. For commercial firms, particularly in the tropics or humid climates, a cold chain from processing to distribution needs to be prioritized above everything else. Though ambient storage is more cost-saving, it is usually reserved for commodity products having a high rate of turnover or products with stabilizing additives.

1. **Analysis of Natural Food-Grade Additives:**

There is vast potential for future studies on extending the shelf life of sponge cakes with natural and safe food-grade additives. A study on antioxidants such as ascorbic acid and tocopherols, humectants such as glycerol and sorbitol, and antimicrobial compounds such as plant extracts or essential oils may produce positive results in inhibiting spoilage without sacrificing softness and moisture and without affecting flavour. Moreover, this research highlights the importance of conducting more research on the stability of macronutrients, particularly lipids and proteins, in sponge cakes. A thorough understanding of lipid oxidation and protein denaturation is necessary since such reactions can have a negative impact on the flavour, aroma, texture, and structure of the cake.

**4. Recommendations for Research Methodology:**

Subsequent studies should include longer observation time frames longer than seven days, along with more detailed sampling techniques. The inclusion of sensory panels would enhance the agreement between instrumental measurements and consumer acceptability. Furthermore, determining the economic viability and sustainability of different packaging formats can significantly increase the relevance of these studies with respect to actual industrial practices.

**Gaps Identified:**

1. **Shortage of Practical Case Studies:** Notwithstanding that the recommendations are grounded in research, there exists a dearth of concrete case studies illustrating the successful application of these practices in small-scale bakeries. The incorporation of practical examples would significantly augment the relevance of the recommendations.
2. **Consumer Perception and Feedback:** The current focus on consumer packaging and storage orientations is narrow. Consumer comments obtained through surveys or focus groups may have the potential to affect packaging and marketing strategy decisions.
3. **Regulatory Considerations:** The impact of food safety law and compliance demands on the selection of packaging materials and additives is an area not widely studied. Meeting these considerations could be critical for small producers as they operate within the law.
4. **Long-Term Economic Analysis:** While the viability and sustainability of alternative packaging are mentioned, a complete long-term economic assessment proving the cost-benefit analysis of a number of approaches would be beneficial.
5. **Impact of Food Trends:** The new food trends, such as the increasing popularity of organic and vegetarian foods, have not been studied seriously. Understanding how these trends influence packaging and storage behaviour can enhance the relevance of this study with a more dynamic market situation.

By bridging these gaps determined and implementing the suggested measures, the bakery industry—especially artisanal and small-scale producers—can significantly improve the safety, appeal, and shelf life of sponge cake products, thereby addressing consumer demand and food safety requirements.

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CONCLUSION:-

In the fragile realm of bakery items, where freshness, moisture, and texture are the parameters of quality, this experiment took a pragmatic voyage through shelf life and science. By packaging sponge cake samples in two different materials, polyethylene and aluminium, and storing them at varying temperatures, we set out to see how even the humblest dessert reacts to the chemical dynamics of its surroundings.

Our results drew a clear picture: Aluminium packaging combined with refrigeration emerged as the winner of freshness, maintaining the sponge cake's moisture, structure, and overall quality for a longer period. On the other hand, polyethylene at ambient conditions promoted spoilage, being less effective in protecting against environmental stressors.

In addition to the fundamental parameters like water activity, pH, and ash content, the discovery of techno-functional characteristics and starch stability brought new dimensions to our knowledge. These finer, though relevant, characteristics unveiled the fact that shelf life is not merely about avoiding spoilage—it's about preserving usability and quality through time.

This research not only arms local bakeries and food manufacturers with wiser, science-based packaging strategies but also opens the door to new avenues, such as incorporating natural additives or researching protein and lipid stability for a more integrated preservation model. With food waste and product deterioration still industry giants, such cutting-edge thinking is the need of the hour.

In the end, this research reminds us that food chemistry is not just about numbers—it's about materials, storage, and science getting along to preserve what we love best: the taste, texture, and happiness of good food.

**Appendix:**

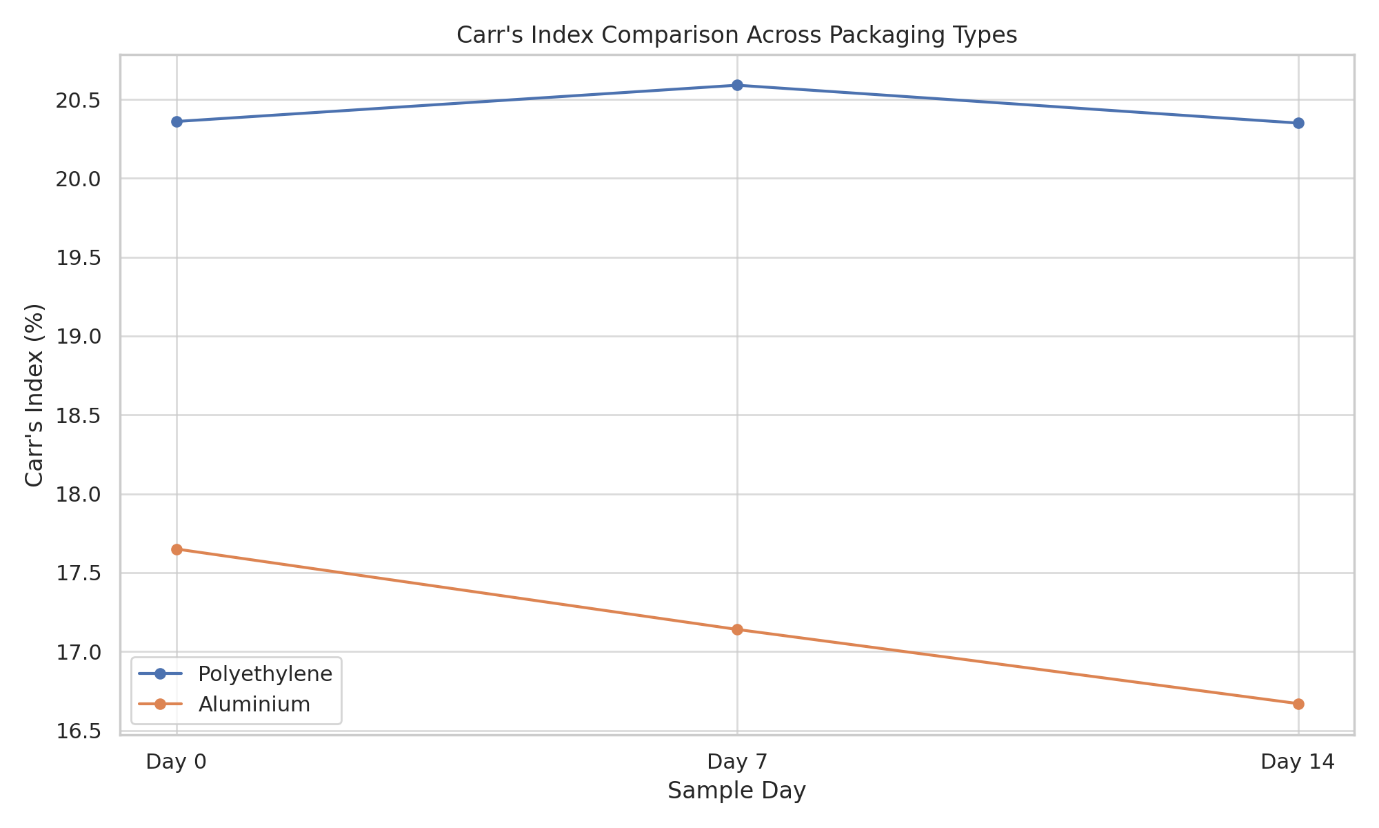
**Techno-Functional Properties of Powdered Sponge Cake**

**Table A1: Techno-Functional Properties Across Packaging and Storage Conditions**

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| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sample Day** | **Packaging Type** | **Storage Temp** | **Weight of Powder (g)** | **Volume of Powder (mL)** | **Bulk Density (g/mL)** | **Tapped Density (g/mL)** | **Carr’s Index (%)** | **Hausner Ratio** |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Day 0 | - | - | 2.0 | 15.0 | 0.133 | 0.167 | 20.36 | 1.26 |
| Day 7 | Polyethylene | Ambient | 2.0 | 14.8 | 0.135 | 0.170 | 20.59 | 1.26 |
| Day 7 | Aluminium | Refrigerated | 2.1 | 14.5 | 0.145 | 0.175 | 17.14 | 1.21 |
| Day 14 | Polyethylene | Ambient | 2.0 | 14.6 | 0.137 | 0.172 | 20.35 | 1.26 |
| Day 14 | Aluminium | Refrigerated | 2.2 | 14.7 | 0.150 | 0.180 | 16.67 | 1.20 |

**Figure A1: Carr’s Index Comparison Across Packaging Types**



**Figure A2: Hausner Ratio Comparison Across Packaging Types**

A graph showing a number of different types of packaging

AI-generated content may be incorrect.

**Figure A3: Bulk vs. Tapped Density Comparison**

A graph showing different colored lines

AI-generated content may be incorrect.

These results provide an overview of how packaging type and storage temperature influence the flow and compaction properties of powdered sponge cake, aiding in shelf-life analysis and product stability assessment for bakery items.

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