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Original Research Article

Evaluating the Impact of Composite Flour Blends on the Sensory and Physical Properties of Sponge Cakes

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Abstract: The present study investigated the storage stability of sponge cakes at room temperature with the aim of evaluating the influence of different flour combinations on the colour, taste, aroma, aftertaste, and overall quality of sponge cakes. Additionally, this study examined the shelf life of cakes stored under ambient conditions. A trained panel conducted a descriptive sensory analysis of genoise sponge cake samples made with different flours using a linear scale to assess their shape, colour, aroma, taste (sweetness), and aftertaste. The mean scores for cake colour showed that all samples had the characteristic colouring of genoise sponge cake. The aroma ratings were pleasant for all samples, and sweetness was moderate. The aftertaste was pleasant for two of the samples (W12 and S12), while the third sample (P12) had a slightly distinct aftertaste. The addition of potato and soybean flours positively affected acceptability, but the control sample (W12) scored the highest overall acceptability, indicating a strong preference for all samples. After three days, the cakes remained visually appealing but deteriorated by day six, and the S12 sample became excessively oily, whereas the W12 and P12 samples developed significant mould. These findings suggest that sponge cakes should not be stored for more than three days at 28-30°C.

Keyword: Sponge cake, composite flour, storage stability, sensory evaluation, cake quality.

INTRODUCTION

A sponge cake is a bakery product that undergoes a transformation from a fluid batter into a porous solid during baking, resulting in a significant increase in volume. This process involves simultaneous mass and heat transfer as well as biochemical reactions and physical transformations (Purlis *et al.*, 2021). According to Canali *et al.*, (2020), an increase in the volume of most bakery products, such as cakes, is significant because the final product can have a volume twice that of its initial state. The leavening used in the batter of baked products such as cakes is responsible for the increase in volume(Asamoah *et al.*, 2023; Canali *et al.*, 2020). In the bakery industry, cakes are leavened with air, and the cake quality depends on factors such as the ingredients used to prepare the batter, aeration of the batter, and processing conditions (Chaiya & Pongsawatmanit, 2011; Hesso *et al.*, 2015). Asamoah *et al.*, (2023) adds that the batter is created by aerating the liquid mixture to produce a foam structure through mechanical mixing with the goal of producing the final product, which is a complex emulsion system. Batter is made by aerating a liquid mixture to produce a foam structure through mechanical mixing. This foam structure, which is a complex emulsion system, is essential for achieving the desired texture and flavour of the final product. The aeration process helps incorporate air into the mixture, creating small bubbles that provide a light and tender crumb structure (Fellows, 2022; Hu & Meng, 2024). The aeration process also helps improve the batter's ability to retain moisture, which is crucial for achieving the desired mouthfeel (Awuchi *et al.*, 2019; Cappelli *et al.*, 2020; Hesso *et al.*, 2015). (Chaiya & Pongsawatmanit, 2011) adds that the creation of a batter through aeration and mechanical mixing is a critical step in the production of high-quality baked goods.

Cake components, according to Ali *et al.*, (2023) are important in determining its internal structure and texture. The utilization of whole eggs in the creation

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of cake batters results in the development of minute bubbles within the crumb of the cake, leading to a smooth and silky texture. For instance, when whole eggs are used in the cake batter, they release carbon dioxide as they cook, creating tiny bubbles that capture air and help create a tender airy crumb that contributes to the cake's overall softness (Pycarelle & Delcour, 2020). Alternatively, a process based on egg yolks, which includes additional shortening, improves the structural qualities of both the batter and baked cakes(Indrani & Rao, 2008; Yang & Baldwin, 2017). For instance, one study by Agrahar-Murugkar *et al.,* (2016) found that replacing a portion of the shortening in cake batter with egg yolks resulted in a cake that was not only lighter in texture, but also had improved structural stability. Genoise according to Foskett *et al.,* (2019), is an Italian sponge cake that depends on egg foam to produce it. Air is incorporated into beaten eggs to create a light and airy structure, resulting in a delicate sponge texture. Lee *et al.,* (2024) reiterated the role of baking powder as a leavening agent, noting that it is utilized in sponge cake preparation and should be incorporated at the final stage of mixing ingredients. Kowalska *et al.,* (2020) adds that the addition of baking powder to sponge cake recipes may enhance the volume of the final product.

Other flour types, aside from wheat meal, have been studied for the production of lower-cost cakes and better quality based on consumer acceptance (Turabi *et al.,* 2008). In 1964, the Food and Agriculture Organization (FAO) targeted the reduction of support costs for temperate countries such as Ghana by promoting the use of indigenous crops, such as potatoes, soybeans, yams, maize, and others, in partial wheat flour substitution (Amagloh *et al.,* 2023). The FAO reported that the use of composite flour in various food products would be economically beneficial if wheat imports could be reduced or even eliminated, and the demand for bread and pastry products could be fulfilled using domestic products rather than wheat (Jisha *et al.,* 2008; Y. Wang & Jian, 2022). Therefore, the adoption of composite flour has the potential to not only reduce the economic burden of wheat imports but also to promote the use of local ingredients and support domestic food production. This could lead to a more sustainable food system and improve countries' self-sufficiency in terms of food supply. By incorporating composite flour into the manufacturing process of bread and pastry products, it may be possible to meet the demand for these items, while also supporting the local economy. Gómez *et al.,* (2008) made use of composite flour in the preparation of cake which was prepared from various types of flour such as wheat-chickpea flour blends, rice flour and flour obtained from wheat, rye, and barley. In their study, Gómez *et al.,* (2008) found that the use of composite flour in cake preparation resulted in a denser and more flavourful final product than traditional single-grain flours. Additionally, they noted that the type of flour blend used had a significant effect on the texture and nutritional content of the cake.

A major problem with cakes is the propensity for rapid staleness. The composition and proportions of ingredients utilised in cake production significantly influence the resultant texture and shelf life of the product (Cauvain, 1998; Fadda *et al.,* 2014). One of the significant factors that can impact the shelf-life and quality of cakes is the storage temperature (Cauvain & Young, 2010; Hesso *et al.,* 2015; Yan *et al.,* 2020). The storage of cakes in a low-temperature environment, such as a refrigerator maintained at 4°C, can contribute to an extended preservation period (Hesso *et al.,* 2015). Storing cakes at room temperature can lead to a range of adverse effects. According to Hesso *et al.,* (2015), the physicochemical changes that occur in the starch and lipid components of cake crumb during storage are a major contributing factor to the staling process. Specifically, the crystallisation of these key components accelerates when cakes are stored at room temperature, leading to a rapid deterioration of freshness and texture (Cauvain & Young, 2010). High-quality cakes can be described as having different qualities, including high volume, uniform crumb texture, softness, and long shelf life with staling tolerance (Gelinas *et al.,* 1999; Offia Olua & Nwakwoke, 2014). (Yazici & Ozer, 2021), suggested that it is economically necessary to keep cakes fresh because of their limited shelf life; thus, additives, such as modified starch, can be used to improve their consistency. In this regard, the study sought to prepare a genoise sponge cake from composite flour made up of wheat-potato flour blend and wheat-soya bean flour blend, compare the physical changes of the freshly baked and stored for 6 days, and evaluate the sensory attributes of the fresh genoise sponge cakes. These findings could provide valuable insights for bakeries and retailers of cakes on the possible effect of storing cakes at ambient temperature.

MATERIALS AND METHODS

Sources of Raw Materials

Wheat, potato, soybean, sugar, eggs, and margarine flours were obtained from a local market in Takoradi, Ghana. All ingredients were stored separately in airtight containers at room temperature (28°C).

Preparation of Cake

Genoise sponge cakes were prepared by the boiling method using the recipe by Foskett *et al.,* (2019) with little modification by mixing wheat-potato flour, wheat-soy bean flour at different levels, and wheat flour only as a control, labelled as W12, S12, and P12, as presented in Table 1 and Figure 1. After baking, the cake samples were kept at room temperature for cooling for an hour, and then half of each sample was sliced for evaluation using a sensory panel. The other half of the cake samples was stored for up to six days from the production date.

Table 1: Formulation of Genoise Sponge Cake Samples

	Cake samples		
Ingredients	**W12**	**P12**	**S12**
Eggs	15 pieces	15 pieces	15 pieces
Castor sugar	250g	250g	250g
Wheat flour	250g	180g	180g
Added flours	_	70g	70g
Butter	75g	75g	75g

W12 – 100% wheat flour (control), P12 – 80% wheat flour and 20% potato flour, S12 – 80% wheat flour and 20% soybeans flour

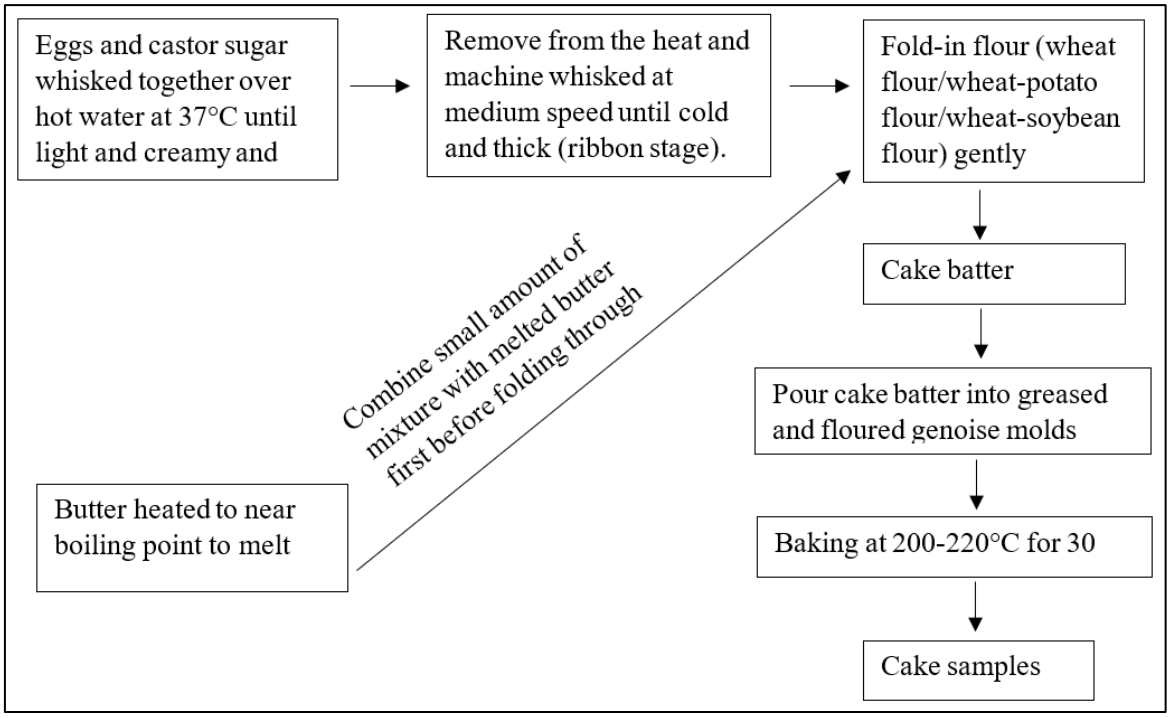


Figure 1: Flow chart for the production of Genoise Sponge Cake

W12 (control) P12 S12

W12 – 100% wheat flour, P12 – 20% potato and 80% wheat flour, S12 – 20% soybeans flour and 80% wheat flour

Figure 2: Freshly baked genoise sponge cake samples

Physical Evaluation of Cake

Crust and crumb of cake samples were visually analysed on the 1st, 3rd, and 6th days at a room temperature of 28.8°C – 30°C for physical changes.

Sensory Evaluation

The sensory evaluation of the different cake samples was carried out using a nine-point linear scale for the descriptive test as described by Goranova *et al.*, (2015) by 10 trained panel from the Department of

Hospitality Management, at Takoradi Technical University. An hour orientation of the panellist was done for them to be familiar with terminology and anchor points on the modified scale from Goranova *et al.*, (2015), as seen in Table 2. The panellists were presented with coded samples and were asked to indicate the extent of likeness of each sensory attribute (shape, aroma, colour, taste (sweetness), and aftertaste). Water was provided to the panellists for use as a neutraliser after each tasting of the cake samples. The panellist also assessed the overall acceptance of the cake samples on a five (5) point hedonic scale by indicating how much they liked or disliked the samples: 5 = Like extremely, 4 = Like very much, 3 = Neither like nor dislike, 2 = Dislike very much, and 1 = Dislike extremely.

Table 2: Sensory attributes with their definitions

Attributes	Definition	Method of evaluation	Scale
Shape	Visual assessment of surface of genoise sponge cake	Presence of large cracks on the surface	0 – 3
		Numerous smaller cracks	3 – 6
		Without cracks, smooth upper surface	6 – 9
Colour	Visual assessment of the colour of the crust and crumb of genoise sponge cake (the colour of the crust should be golden brown and the crumb should have light yellow colour)	A significant discoloration	0 – 3
		Unevenly colour of surface and in the crumb of the cake	3 – 6
		Characteristics colouring of crumb and crust	6 – 9
Aroma	Rating aroma when consuming the genoise sponge cake	Presence of strong unusual aroma	0 – 3
		Slight uncharacteristic aroma	3 – 6
		Pleasant aroma	6 – 9
Taste (sweetness)	Evaluation of the sweet taste of genoise sponge cake	Inadequate pronounced sweet taste	0 – 3
		Moderate sweet taste	3 – 6
		Strong sweet taste	6 – 9
After taste	Evaluation of the after taste of genoise sponge cake after consumption	Pleasant after taste sensation	0 – 3
		Presence of slightly discernible side after taste	3 – 6
		Strong unpleasant after taste	6 – 9

Statistical Analysis

The average means of the responses from the panellists of the sensory evaluation were analysed using a spider chart (radar chart). The statistical analysis was performed using Microsoft excel.

RESULT AND DISCUSSION

Sensory Evaluation of Cake

Figure 3 shows the genoise sponge cake samples evaluated based on their shape, aroma, colour, taste (sweetness), aftertaste, and overall acceptance. With regard to the shape of the sponge cake, the control sample W12 was rated as having no cracks and a smooth upper surface with the highest mean score of 6.40. Sample S12, with a mean score of 5.10 was rated as having numerous smaller cracks, followed by sample P12, which had the presence of large cracks on the surface with a mean score of 4.10. Goranova *et al.*, (2015) in a similar study observed that 100% wheat flour used for the preparation of sponge cake in their study had no cracks on the surface which resulted in higher crumb tenderness, as observed in this study. They added that crumb tenderness resulted in an increase in overall liking value. In another study, Wang *et al.*, (2020) found that the shape of sponge cake with 25% rice flour had no cracks on its upper surface, which is consistent with the present study.

The highest mean score (6.50) for cake colour was noted for both the control (W12) and the sample with 20% soybean flour substitution (S12). The sample with 20% potato flour substitution also had a mean score of 6.10, indicating that all cake samples were rated as having characteristic colouring of the crumb and crust of genoise sponge cake which is usually brown for crust and light yellow for crumb. The light yellow colour of the crumb might have resulted from the yellowish colour of margarine and egg yolk which contains carotenoids. The observations in this study are in line with a study by Goranova *et al.*, (2015) where in their study, where the sponge cake sample which contained 100% wheat flour had a brown crust and the crumb was also light yellow. Akter & Alim (2018) also observed similar colour for cake made with composite flour containing 20% potato flour.

The mean score for aroma and taste increased from 6.50 to 7.40 and 5.20 to 5.90 respectively. All cake samples had a pleasant aroma and moderate sweetness, with the control (W12) having the highest mean in all cases. This is in line with a study conducted by Elsheshetawy (2015), where 100% wheat flour sample (control) also had appropriate aroma intensity and highly rated aroma likeability scores over the course of testing. It can be inferred from the results that the aroma of the cakes was a result of the added flavours. The essence of vanilla used in cake preparation contributed to its aroma.

With regard to the taste of sponge cake samples, the sweetness of the cake is usually a result of the addition of sucrose (sugar). Sanful *et al.,* (2010) supported this finding by indicating that the taste of cakes results from the addition of sweetening agents. Tamanna & Mahmood (2015) adds that the flavour of bakery products results from the aroma compounds produced by enzymatic, fermentative and thermal reactions of sugar and starch during baking, as well as the aroma compounds deliberately added to the products to obtain baked goods with specific aromatic characteristics.

Sample P12 (20% potato flour and 80% wheat flour) had the highest mean score of 3.20 with regards to aftertaste, indicating that it had a slightly distinct taste. However, samples W12 and S12 were found to have no aftertaste, with mean scores of 2.50 and 2.30, respectively, indicating a pleasant taste sensation.

Overall acceptance expresses how the panellists generally accept the product. The mean scores of the samples were quite close (W12 = 4.10, S12 = 4.1, and P12 = 3.5), indicating that the panellists liked all the samples very much, which can be inferred from the results that the panellists were inclined to accept cake from the composite flour. This result agrees well with Sanful *et al.,* (2010)

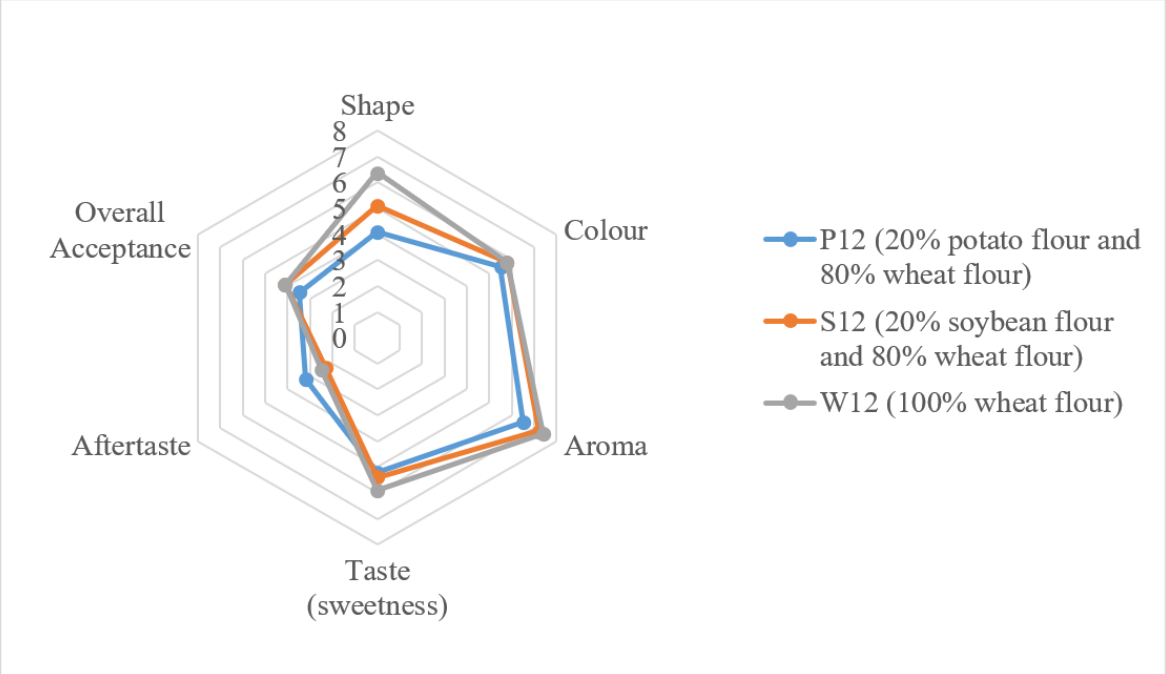


Figure 3: Sensory attribute of sponge cake samples

Overall Acceptance: 1 – Disliked extremely; 2 – Disliked very much; 3 – Neither Liked nor Disliked; 4 – Liked very much; 5 – Liked extremely

Scale: 1 – 1.49 = Disliked extremely, 1.5 – 2.49 = Disliked very much, 2.5 – 3.49 = Neither Liked nor Disliked, 3.5 – 4.49 = Like very much, 4.5 – 5 = Liked extremely

Physical Evaluation of the Sponge Cakes during Storage

The prepared sponge cake samples were stored for 6 days at a temperature of 28.8˚C - 30˚C. On the first day of production, samples W12 and S12, as shown in Figure 4, had a brown crust and light-yellow crumb. However, the crust of sample P12 was brown but uneven in colour, as shown in figure 4. W12 was the tallest and had a centre dome, and S12 and P12 were of the same height; however, P12 was flat, whereas S12 had centre dips. P12 was the crumbiest, W12 was least crumby, while S12 was in between. W12 was also spongy and fluffy.

W12 (control)[a] P12[a] S12[a]

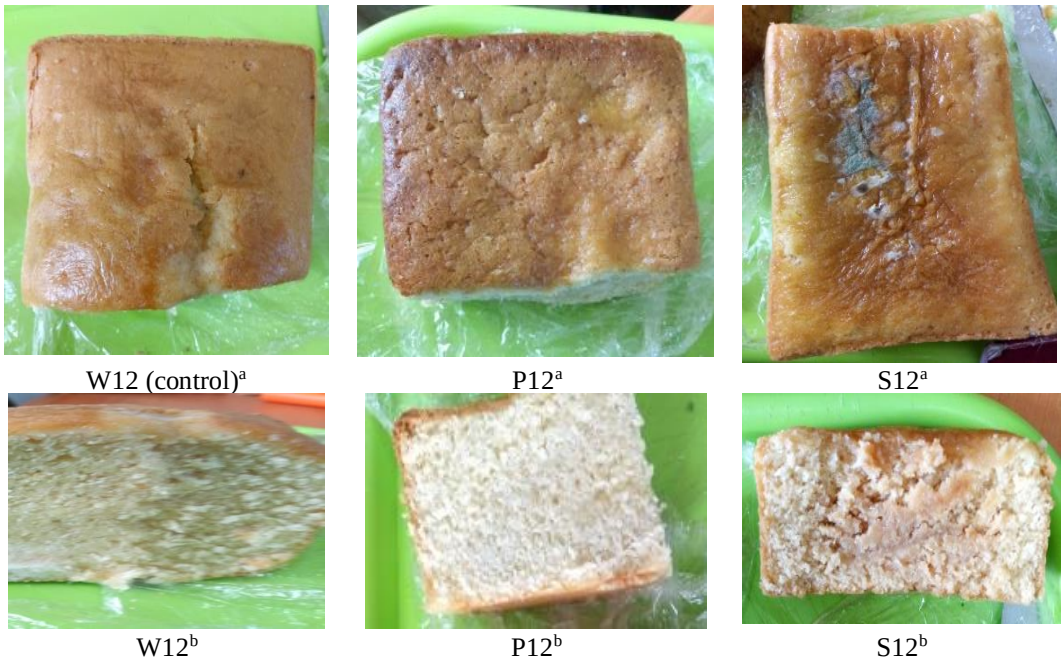
W12 (control)[b] P12[b] S12[b]

W12 – 100% wheat flour, P12 – 20% potato and 80% wheat flour, S12 – 20% soybeans flour and 80% wheat flour

Figure 4: Photograph of (a): top surface and (b) cross section of the baked sponge cake samples on the first day after production

On the third day of storage, sample S12 (20% soybean flour and 80% wheat flour) showed massive oil development. This may have resulted from the fact that soybeans are composed of 7 – 10% oil. Sample P12 (20% potato flour and 80% wheat flour) was doughy, whereas sample W12 (100% wheat flour) was still fluffy. The cake samples appeared to be visually good and attractive.

Noticeable deterioration was observed on the sixth day of storage; sample S12 had greenish moulds growing all over it, had an extra soft texture, and was very oily, as seen in figure 5. Sample W12 was full of white moulds on both the crust and crumb. The crumb and crust also had a dry and hard texture; however, sample P12 had small amounts of moulds on both the crust and crumb, as shown in figure 5.



W12 (control)[a] P12[a] S12[a]

W12[b] P12[b] S12[b]

W12 – 100% wheat flour, P12 – 20% potato and 80% wheat flour, S12 – 20% soybeans flour and 80% wheat flour

Figure 5: Photograph of (a): top surface and (b) cross section of the baked sponge cake samples on the sixth day after production

CONCLUSION

The study suggests that the incorporation of other flours, such as potato flour and soybean flour, into cake recipes can enhance their acceptability, despite the control sample W12 (100% wheat flour) achieving the highest level of "overall acceptability." Sample P12 (20% potato flour and 80% wheat flour) was found to be satisfactory according to the sensory panel. The results indicated that the control sample with the highest crumb tenderness score had the highest overall liking values. However, after three days of storage, the cakes began to deteriorate, and by the sixth day, they were no longer visually appealing. Sample S12 (20% soybean flour and 80% wheat flour) exhibited excessive oiliness, and all three samples, including the control and two samples with composite flours, showed signs of mould growth. These findings suggest that both the control cake (made entirely of wheat flour) and cakes made with composite flours cannot be stored at room temperature for more than three days.

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