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Enhancing the physical properties of biscuits through composite flour of barnyard millet and dragon fruit powder

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Abstract
This study investigates the physical properties of biscuits produced from a composite flour of barnyard millet and dragon fruit powder. Measurements included diameter, thickness, weight, spread ratio, spread factor, bulk density, and water activity. The largest diameter (55.22 mm) and lightest weight (8.04 g) were recorded in treatment T_1, which used a 100:0 ratio of barnyard millet flour to dragon fruit powder. Conversely, treatment T_{11}, with a 50:50 ratio, exhibited the smallest diameter (54.08 mm) and heaviest weight (8.41 g). Significant differences in thickness were observed, with T_1 having the maximum thickness (6.76 mm) while T_{11} showed the minimum (5.89 mm), attributed to gluten dilution. The spread ratio was significantly influenced by all formulations, with T_{11} achieving the highest value (9.13), reflecting an increased spread due to reduced thickness. The spread factor also demonstrated significant variation, peaking at T_3 (112.58). Bulk density ranged from 0.63 g/cm^3 in T_1 to 0.75 g/cm^3 in T_{11}, attributed to moisture content and the hydrophilic nature of dragon fruit powder. Water activity varied between 0.41% and 0.49%, with T_{11} showing the highest value, indicating the impact of dragon fruit fibre on moisture retention. These findings highlight the potential of barnyard millet and dragon fruit powder in enhancing the quality and nutritional profile of biscuits.

Keywords: Biscuits, composite flour, barnyard millet, dragon fruit powder, physical properties

Introduction

Biscuits are popular snacks made from flour, water, fat, and sugar, primarily using wheat flour due to its gluten content. They are cost-effective, have a long shelf life, and come in various sizes and Flavors.

Dragon fruit powder is valued for its shelf life and versatility as a natural colorant and functional ingredient. Spray drying transforms fruit juices into nutrient-rich powder that is easy to transport, reducing costs compared to raw fruits, although it may face issues like stickiness, which can be addressed using carrier materials (Kha *et al*., 2010; Tonny *et al*., 2008) [7, 17].

Millets, particularly barnyard millet (*Echinochloa frumentacea*), have been consumed for centuries but are declining in use. They are nutrient-dense, high in protein and fibre, low in digestible carbohydrates, and beneficial for metabolic disorders like diabetes (Ugare *et al.*, 2014) [18]. Barnyard millet can enhance the nutrient composition of biscuits, especially when combined with dragon fruit flour and peel pectin.

Baked goods are favoured for their convenience and long shelf life. Their low moisture content reduces spoilage risks, allowing for large-scale production (Dhankar, 2013) [6]. Biscuits, in particular, are significant snacks for all ages and efforts are underway to improve their nutritional quality to meet market demands for healthier products (Masoodi and Bashir, 2012) [11]. They are made by mixing ingredients into a dough that is baked without fermentation (Lake and Water-Worth, 1980) [10].

Materials and Methods

Diameter (mm)

Biscuits diameter was measured by placing six biscuits edge-to edge to get the average diameter by Vernier calliper.

Thickness (mm)

Thickness was measured by stacking six biscuits on top of each other and taking average thickness by Vernier calliper (Nouman, 2003) [13].

Spread ratio

Spread ratio was calculated as the ratio of the biscuit diameter to thickness.

$$\text{Spread ratio} = \frac{\text{Diameter (mm)}}{\text{Thickness (mm)}} \times 100$$

Weight (g)

Weight

Weight of biscuits was measured as average of values off our individual biscuits with the help of digital weighing balance (Baljeet *et al*., 2010) [2].

Spread factor

Spread factor of biscuits was measured by the method described in AOAC (2016) [1]. It was determined from the diameter and thickness, with the help of following formula:

$$SF = D/T*CF \times 10$$

CF is a correction factor (1.0) at constant atmospheric pressure.

Bulk density (BD, g/cm^3)

Bulk density was obtained by ratio of weight of volume.

$$\text{Bulk Density (g/cm}^3) = \frac{\text{Mass of sample (g)}}{\text{Volume of sample (cm}^3)} \times 100$$

Water activity (a_w, %)

Water activity of the biscuits was measured using a Decagon's Aqualab Series 3 water activity meter (Pullman, WA) at 25 °C. Biscuit crumb (about 2 g) was evenly placed into plastic cells and was allowed to equilibrate within the headspace of the sealed chamber. The reading was then recorded when the equilibration is achieved (Decagon, 2007) [5].

Physical characteristics of biscuits

1. Diameter (mm) and Weight (g)

The data regarding the diameter and weight of biscuits produced from a composite flour of barnyard millet and dragon fruit powder is presented in Table 1. The different proportions of unfermented barnyard millet flour mixed with dragon fruit powder did not significantly affect the overall mean diameter and weight of the biscuits. Notably, the largest diameter (55.22 mm) and the lightest weight (8.04 g) were recorded for treatment T_1, which used a 100:0 ratio of barnyard millet flour to dragon fruit powder. Conversely, the smallest diameter (54.08 mm) and the heaviest weight (8.41 g) were observed in treatment T_{11}, which had a 50:50 ratio of the two flours. The reduction in diameter for T_{11} may be attributed to an initial increase in spread ratio, influenced by the combined effects of sugar and fibres in the dough. A higher spread ratio is generally more desirable in biscuits, aligning with findings from Chauhan *et al*. (2016) [3].

Table 1: Data on Physical characteristics of biscuits

Treatment	Diameter (mm)	Thickness (mm)	Weight (g)	Speed ratio	Spread factor (SF, %)	Density (BD, g/cm^3)	Water activity (a_w, %)
T_1- 100:0 (BYMF+DFP)	55.22	6.76^{a}	8.04	8.17^{g}	101.56^{e}	0.63^{h}	0.41^{g}
T_2- 95:5 (BYMF+DFP)	55.07	6.65^{ab}	8.15	8.25^{fg}	102.84^{de}	0.65^{gh}	0.42^{fg}
T_3- 90:10 (BYMF+DFP)	54.93	6.56^{abc}	8.23	8.36^{efg}	112.58^{a}	0.65^{fgh}	0.43^{fg}
T_4- 85:15 (BYMF+DFP)	54.86	6.43^{bcd}	8.24	8.45^{defg}	104.59^{cde}	0.67^{efgh}	0.43^{efg}
T_5- 80:20 (BYMF+DFP)	54.86	6.32^{cde}	8.26	8.54^{cdef}	105.55^{bcde}	0.67^{efg}	0.44^{def}
T_6- 75:25 (BYMF+DFP)	54.82	6.26^{cde}	8.30	8.64^{cde}	105.67^{bcde}	0.68^{def}	0.44^{def}
T_7- 70:30 (BYMF+DFP)	54.72	6.26^{cde}	8.31	8.75^{bcd}	106.50^{abcde}	0.70^{cde}	0.46^{cde}
T_8- 65:35 (BYMF+DFP)	54.52	6.15^{def}	8.33	8.77^{bcd}	107.43^{abcde}	0.72^{bcd}	0.46^{bcd}
T_9- 60:40 (BYMF+DFP)	54.37	6.04^{ef}	8.38	8.85^{abc}	108.73^{abcd}	0.73^{abc}	0.47^{abc}
T_{10}- 55:45 (BYMF+DFP)	54.19	5.89^{f}	8.40	9.04^{ab}	110.17^{abc}	0.74^{ab}	0.49^{ab}
T_{11}- 50:50 (BYMF+DFP)	54.08	5.89^{f}	8.41	9.13^{a}	111.61^{ab}	0.75^{a}	0.49^{a}
Mean	54.70	6.29	8.28	8.63	107.02	0.69	0.45
S.E.m.±	1.03	0.11	0.15	0.12	2.07	0.01	0.01
C.D. 5%	NS	0.32	NS	0.34	6.09	0.04	0.03
C.D. 1%	NS	0.43	NS	0.47	8.27	0.05	0.04

2. Thickness (mm)

The thickness of the biscuits made from the composite flour of barnyard millet and dragon fruit powder is summarized in Table 1. There were significant differences in thickness among the treatments. Treatment T_1 exhibited the maximum thickness (6.76 mm), closely followed by T_2 (6.65 mm) and T_3 (6.56 mm). In contrast, the minimum thickness (5.89 mm) was recorded for T_{11}, which was comparable to T_{10} (5.89 mm), T_9 (6.04 mm), and T_8 (6.15 mm). The reduced thickness can be attributed to gluten dilution, as noted. Furthermore, reported that dried pitaya powder contains a high crude fiber content (23.75%). The high water absorption characteristics of this insoluble fiber (56.50%) may lead to increased water attraction, thereby reducing dough viscosity and resulting in decreased thickness. These findings are consistent with conclusions drawn by Silky and Tiwari (2014) [16], and Qayyum *et al*. (2017) [15].

3. Spread Ratio

The spread ratio data for the biscuits produced from a composite flour of barnyard millet and dragon fruit powder is presented in Table 1. The results indicate that all formulations significantly influenced the spread ratio of the biscuits. Among the treatments, T_{11} achieved the highest spread ratio (9.13), comparable to T_{10} (9.04), T_9 (8.85), T_8 (8.74), and T_7 (8.75). In contrast, T1 had the lowest spread ratio (8.17), which was similar to T_2 (8.25), T_3 (8.36), and T_4 (8.45). The increase in spread ratio can be attributed to the reduction in biscuit thickness resulting from the incorporation of dragon fruit powder. The spread ratio is an important indicator of flour quality and the biscuits' ability to rise, with higher ratios generally indicating greater desirability (Chauhan *et al*., 2016) [3]. An overall increase in spread ratio was observed with higher flour substitutions, a trend consistent with findings from other studies (Silky and Tiwari, 2014; Qayyum *et al*., 2017) [16, 15].

4. Spread Factor

The spread factor data for the biscuits produced from the composite flour of barnyard millet and dragon fruit powder is detailed in Table 1. Significant effects on spread factor were observed across all treatments. The highest spread factor was recorded in T_3 (112.58), which was comparable to T_{11} (111.61), T_{10} (110.17), T_9 (108.73), T_8 (107.43), and T_7 (106.50). Conversely, T_1 had the lowest spread factor (101.56), similar to T_2 (102.84). The increase in spread factor can be linked to the enhanced spread ratio resulting from the addition of dragon fruit powder Silky and Tiwari, 2014 [16] noted that increasing kodo millet flour reduced thickness while enhancing both spread ratio and spread factor in soya-based millet biscuits.

5. Bulk Density (g/cm³)

The bulk density data for the biscuits produced from composite flour of barnyard millet and dragon fruit powder is summarized in Table 1. Significant differences in bulk density were observed among the treatments. T_{11} had the highest bulk density (0.75 g/cm³), closely followed by T_{10} (0.74 g/cm³), T_9 (0.73 g/cm³), T_8 (0.72 g/cm³), and T_7 (0.70 g/cm³). T_1 exhibited the lowest bulk density (0.63 g/cm³), comparable to T_2 (0.65 g/cm³), T_3 (0.65 g/cm³), and T_4 (0.67 g/cm³). The higher bulk density in biscuits made with unfermented barnyard millet flour and dragon fruit powder is attributed to the overall weight and moisture content of the biscuits. This may result from the decreased volume of biscuits containing dragon fruit powder, which has a hydrophilic nature and higher water absorption capacity compared to barnyard millet flour (Pawde *et al*., 2020) [14].

6. Water Activity (%)

The water activity data for the biscuits produced from composite flour of barnyard millet and dragon fruit powder is presented in Table1. The results showed significant effects on water activity across all treatments. The highest water activity was recorded in T_{11} (0.49%), similar to T_{10} (0.49%) and T_9 (0.47%), followed by T_8 (0.46%) and T_7 (0.46%). In contrast, T_1 had the lowest water activity (0.41%), comparable to T_2 (0.42%), T_3 (0.43%), and T_4 (0.43%). Water activity is a crucial factor that indirectly reflects biscuit texture and is important for storage stability. The water activity ranged from 0.41% to 0.49%, with T_{11} (50:50% BYMF + DFP) showing the highest value. The increased water activity in these biscuits is likely due to the higher water-holding capacity of fibres in dragon fruit powder (Krishnan *et al.*, 2011; Pawde *et al.*, 2020) [14].

Conclusion

The study assessed the physical properties of biscuits produced from a composite flour of fermented barnyard millet and dragon fruit powder. The findings revealed that while the incorporation of dragon fruit powder did not significantly affect the overall mean diameter and weight of the biscuits, it resulted in a notable decrease in diameter but an increase in weight compared to biscuits made solely with barnyard millet flour.

The thickness of the biscuits varied significantly across treatments, with the highest thickness recorded in the control sample. In terms of spread ratio, formulations with higher dragon fruit powder led to an increased spread ratio, attributed to reduced thickness, indicating that the biscuits' quality improved with this substitution. The spread factor also increased in biscuits containing dragon fruit powder, correlating with the rise in spread ratio.

Additionally, bulk density measurements indicated a decrease with the incorporation of dragon fruit powder, which is beneficial for the formulation of complementary foods due to its lightweight nature. Finally, water activity was highest in the control biscuits, highlighting the impact of dragon fruit powder on moisture retention, which is crucial for texture and shelf-life.

Overall, the study demonstrates that using dragon fruit powder in barnyard millet biscuits can enhance certain physical properties, making them more desirable while retaining functional attributes suitable for various food applications.

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