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Development of Muffins using Flaxseed and Strawberry Powder and their physicochemical properties

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Abstract
This study was designed to develop the muffins using flax seeds and strawberry powder. The developed muffins were subjected for sensory analysis, proximate composition and texture profile analysis and also determined the color properties of the developed muffins. The results indicated that the flaxseed powder is notably higher in protein, fat, dietary fibre, and energy content compared to strawberry powder. Conversely, strawberry powder contains significantly more carbohydrates, total sugars, and vitamin C. These compositional differences highlight the distinct nutritional profiles of the two powders, which could influence their functional applications in food products.
The sensory analysis results of muffins developed using flaxseed powder and strawberry powder, comparing a control sample with three treatments labeled T_1, T_2, and T_3. The sensory attributes evaluated include colour, flavour, taste, texture, and overall acceptability, each scored on a scale where higher values indicate better sensory quality. For colour, the control muffin scored 8.12 ± 0.42, while T_1, T_2, and T_3 scored progressively higher at 8.76 ± 0.28, 8.34 ± 0.38, and 8.58 ± 0.31 respectively. In terms of flavour, the control had a score of 8.04 ± 0.36, with T_1 scoring 8.68 ± 0.25, T_2 at 8.28 ± 0.34, and T_3 at 8.46 ± 0.29. The taste scores followed a similar trend, with the control at 8.10 ± 0.40, T_1 at 8.74 ± 0.27, T_2 at 8.30 ± 0.36, and T_3 at 8.52 ± 0.32. For texture, the control scored 8.18 ± 0.35, while T_1, T_2, and T_3 scored 8.82 ± 0.24, 8.40 ± 0.33, and 8.60 ± 0.30 respectively. Finally, the overall acceptability scores were 8.26 ± 0.31 for the control, 8.94 ± 0.20 for T_1, 8.48 ± 0.28 for T_2, and 8.70 ± 0.25 for T_3. Overall, all treatment muffins showed higher sensory scores compared to the control, with T_1 consistently achieving the highest values across all attributes, indicating that the addition of flaxseed and strawberry powders improved the sensory qualities of the muffins. The proximate composition of developed muffins using flaxseed powder and strawberry powder showed the following values: Colour was 8.12 ± 0.42 for the Control, 8.76 ± 0.28 for T_1, 8.34 ± 0.38 for T_2, and 8.58 ± 0.31 for T_3; Flavour was 8.04 ± 0.36 for the Control, 8.68 ± 0.25 for T_1, 8.28 ± 0.34 for T_2, and 8.46 ± 0.29 for T_3; Taste was 8.10 ± 0.40 for the Control, 8.74 ± 0.27 for T_1, 8.30 ± 0.36 for T_2, and 8.52 ± 0.32 for T_3; Texture was 8.18 ± 0.35 for the Control, 8.82 ± 0.24 for T_1, 8.40 ± 0.33 for T_2, and 8.60 ± 0.30 for T_3; and Overall acceptability was 8.26 ± 0.31 for the Control, 8.94 ± 0.20 for T_1, 8.48 ± 0.28 for T_2, and 8.70 ± 0.25 for T_3.
The L* value, indicating lightness, decreases progressively from 41.24 ± 0.18 in the Control group to 37.86 ± 0.22 in T_3, showing that muffins become darker with each treatment. The a* value, representing the red-green spectrum, increases from 7.42 ± 0.04 in Control to 10.24 ± 0.10 in T_3, indicating a shift toward a redder hue. Similarly, the b* value, which measures the yellow-blue spectrum, rises from 18.14 ± 0.21 in Control to 21.58 ± 0.36 in T_3, suggesting increased yellowness in the muffins as treatments progress. The last developed muffins that were fortified with flaxseed powder and strawberry powder displayed positive morphological and sensory qualities. The product had soft texture, crust formation was even, appealing colour and acceptable volume expansion after baking. Higher concentration of flaxseed powder gave a somewhat darker crumb colour because of its natural colouring and strawberry powder increased aesthetic appeal and flavour base of the muffins. Flaxseed powder has higher protein, fat, dietary fiber, and energy, while strawberry powder contains more carbohydrates, sugars, and vitamin C. These differences define their distinct nutritional profiles and influence their functional roles in food products. Therefore, selection depends on the desired nutritional and sensory attributes of the muffins.
Keywords: Muffins, flaxseeds, strawberry, Texture profile analysis

Introduction
Strawberries (Fragaria × ananassa) are prized for their remarkable nutritional and medicinal qualities in addition to their pleasing flavor and color. They are abundant in vitamins, antioxidants and bioactive substances that support general health and help prevent a number of illnesses. Consuming strawberries on a regular basis whether they are fresh or processed like powder can have a number of physiological advantages (Giampieri et al. 2012).
A fruit with great nutritional value and versatility, strawberries hold great promise for the development of functional foods. Its shelf life and use in baked goods are improved by turning it into a powder. Strawberry powder is used in this study to enhance the muffins nutritional value and sensory appeal making them healthier and more enticing. Strawberries are a very nutritious fruit

with a high water content (about 90–91%) which makes them refreshing and low in calories. They are a great source of vitamin C making up a large amount of the daily requirement that supports healthy skin and strengthens immunity (Basu et al., 2014). Strawberries also contain dietary fiber which promotes gut health and aids in digestion in addition to vitamin C. Additionally they are high in natural sugars which give them a pleasing sweetness without consuming a lot of energy. Strawberries high concentration of antioxidants such as anthocyanins and flavonoids which help fight oxidative stress and lower the risk of chronic diseases is one of their main characteristics. Strawberries also contribute to general health and wellbeing by providing vital minerals like potassium and trace amounts of folate. They are a perfect addition to food products like muffins because of their well-balanced nutritional profile which also improves their sensory appeal.

Flaxseed is prized for its fiber which is used to make linen in the textile industry in addition to its seeds. Flaxseed cultivation is advantageous from a sustainability standpoint because it requires fewer inputs than many other crops. When incorporated into crop rotation systems it enhances soil health and adds to crop diversification. Flaxseeds' significance as a commercial crop has increased due to the growing demand for it in the food and health sectors. In the agricultural and food processing industries in particular flaxseed is essential to the economy. Both domestic and foreign markets are seeing an increase in demand as people become more aware of its health benefits. Farmers traders and food manufacturers now have more opportunities as a result. Higher financial returns result from the processing of flaxseed into value-added products like flaxseed oil flour and fortified foods. By using flaxseed in functional products bakers can reach health-conscious consumers boosting their profitability and competitiveness in the market (Potter & Hotchkiss, 2012). The above mentioned facts, this study was under taken to undertaken to develop the muffins

Materials and methods

Selection of raw materials

The raw materials such as flax seeds, strawberry, sugar, ghee, egg, flaxseed powder, strawberry powder, Baking soda, baking powder, salt, vanilla essence were purchased from local market, Hyderabad. The chemicals required were of analytical food grade procured from Himedia laboratory, Mumbai.

Development of Muffins using Flaxseed and Strawberry Powder

Table 1 Formulation table for development of muffins

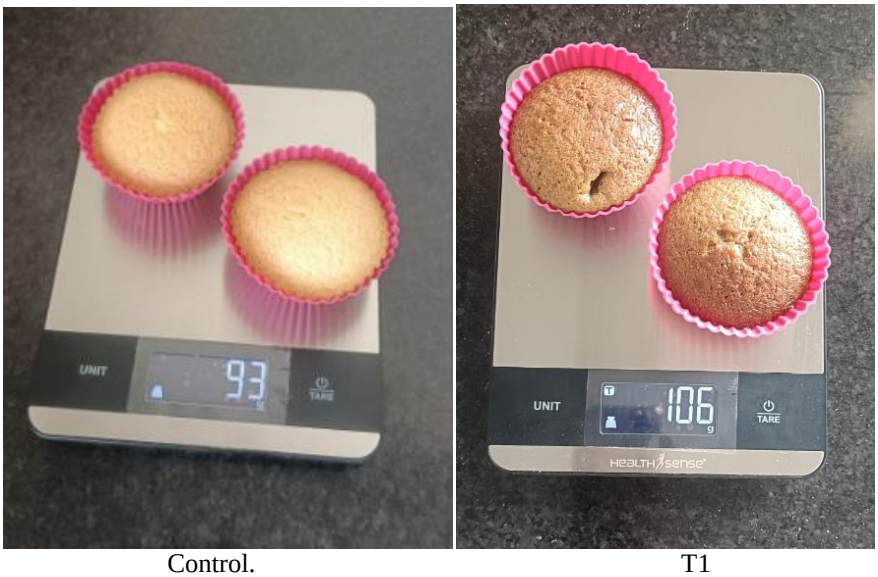
Table 3.1 Formulation of developed muffins with flaxseed powder and strawberry powder

Ingredients	Control (C)	T1	T 2	T 3
Flour	32	28	26	24
Sugar	22	22	22	22
Ghee	19	15	15	15
Egg	23	23	23	23
Flaxseed powder	-	3	3	3
Strawberry powder	-	5	7	9
Baking powder	1	1	1	1
Baking Soda	0.5	0.5	0.5	0.5
Salt	0.5	0.5	0.5	0.5
Vanilla essence	2	2	2	2

Flowchart for the preparation of muffins

Weigh all dry ingredients
(flour, baking soda, baking powder)
⇓
Mix dry ingredients thoroughly
⇓
Beat egg + sugar + butter
⇓
Add vanilla essence
⇓
Prepare smooth batter
⇓
Transfer batter into muffin moulds
⇓
Bake at 180°C for 25 minutes
⇓
Remove from oven
⇓
Cool to room temperature
⇓
Pack and Evaluate Samples

Figure 1 Preparation of muffins using flaxseed powder and strawberry powder



Control. T1

T3 **T4**

Figure 2: Muffins developed using flaxseed powder and strawberry powder

Proximate analysis

The Moisture content of muffin samples was determined using a hot air oven drying method. Ash content was determined by incinerating the dried sample in a muffle furnace at 550°C until light grey ash was obtained. The fat content of the muffin samples was determined using the Soxhlet extraction method. Kjeldahl method was used to estimate the protein content of muffin samples.

Color properties

Colour parameters such as lightness, darkness and yellowness (L*, a* and b*) of meat analogues were determined using a colourimeter (Colour flex CX2748, Hunter Lab, USA).

Texture profile analysis

The texture profile analysis of muffins was conducted by evaluating seven textural parameters: hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience. Textural properties provided valuable insights into how the plant proteins influenced the eggless muffins textural attributes compared with conventional cookies.

The texture profile analysis of muffins was performed using a Brookfield Texture Analyzer (Model: Ametek Brookfield-CT 100). Data were analyzed with Texture Pro-CT software, following the method established by Jaico *et al*. (2022). Instrumental settings included a pre-test speed of 2 mm/s, a post-test speed of 1 mm/s, a 50 N load cell, and a trigger load of 7 g. The recorded textural parameters were hardness, cohesiveness, gumminess, springiness, and chewiness. Samples were placed on a heavy-duty platform and underwent two analysis cycles to mimic human chewing. The samples were anaysed for three times for two compression cycles.

Sensory evaluation

The developed muffins and control samples were subjected for organoleptic evaluation using 60 untrained panel members by 9 point hedonic scale (Diaz et al., 2022).

Statistical analysis

All the data were subjected to statistical analysis to calculate the mean and standard deviation. The values were expected as mean ± SD.

Results and Discussion

Table 2 Proximate composition of flaxseed powder and strawberry powder

Chemical composition (100 g)	Flaxseed powder	Strawberry powder
Carbohydrates (g/100 g)	28.90 ± 1.10	74.50 ± 1.00
Total sugars (g/100 g)	1.60 ± 1.20	58.2 ± 1.40
Moisture (g/100 g)	6.50 ± 1.24	5.80 ± 1.30
Protein (g/100 g)	18.30 ± 1.20	7.20 ± 2.14
Fat (g/100 g)	42.20 ± 1.10	1.10 ± 2.14
Dietary fibre (g/100 g)	27.30 ± 1.20	14.60 ± 1.10
Ash (g/100 g)	3.40 ± 2.10	2.80 ± 1.40
Vitamin C (mg/100 g)	0.60 ± 1.10	52.40 ± 1.80
Energy (kcal/100 g)	534.00 ± 2.40	356.00 ± 2.14

Values are expressed as Mean ± SD (n=3)

Flaxseed powder is notably higher in protein, fat, dietary fibre, and energy content compared to strawberry powder. Conversely, strawberry powder contains significantly more carbohydrates, total sugars, and vitamin C. These compositional differences highlight the distinct nutritional profiles of the two powders, which could influence their functional applications in food products.

The proximate composition of flaxseed powder and strawberry powder per 100 grams is as follows: flaxseed powder contains 28.90 grams of carbohydrates, 1.60 grams of total sugars, 6.50 grams of moisture, 18.30 grams of protein, 42.20 grams of fat, 27.30 grams of dietary fibre, 3.40 grams of ash, 0.60 milligrams of vitamin C, and provides 534.00 kilocalories of energy. In comparison, strawberry powder contains 74.50 grams of carbohydrates, 58.2 grams of total sugars, 5.80 grams of moisture, 7.20 grams of protein, 1.10 grams of fat, 14.60 grams of dietary fibre, 2.80 grams of ash, 52.40 milligrams of vitamin C, and provides 356.00 kilocalories of energy per 100 grams.

Table 3 Sensory analysis of developed muffins using flaxseed powder and strawberry powder

S.No	Variables	Control	T_1	T_2	T_3
1	Colour	8.12 ± 0.42	8.76 ± 0.28	8.34 ± 0.38	8.58 ± 0.31
2	Flavour	8.04 ± 0.36	8.68 ± 0.25	8.28 ± 0.34	8.46 ± 0.29
3	Taste	8.10 ± 0.40	8.74 ± 0.27	8.30 ± 0.36	8.52 ± 0.32
4	Texture	8.18 ± 0.35	8.82 ± 0.24	8.40 ± 0.33	8.60 ± 0.30
5	Overall acceptability	8.26 ± 0.31	8.94 ± 0.20	8.48 ± 0.28	8.70 ± 0.25

The table 3 presents the sensory analysis results of muffins developed using flaxseed powder and strawberry powder, comparing a control sample with three treatments labeled T_1, T_2, and T_3. The sensory attributes evaluated include colour, flavour, taste, texture, and overall acceptability, each scored on a scale where higher values indicate better sensory quality. For colour, the control muffin scored 8.12 ± 0.42, while T_1, T_2, and T_3 scored progressively higher at 8.76 ± 0.28, 8.34 ± 0.38, and 8.58 ± 0.31 respectively. In terms of flavour, the control had a score of 8.04 ± 0.36, with T_1 scoring 8.68 ± 0.25, T_2 at 8.28 ± 0.34, and T_3 at 8.46 ± 0.29. The taste scores followed a similar trend, with the control at 8.10 ± 0.40, T_1 at 8.74 ± 0.27, T_2 at 8.30 ± 0.36, and T_3 at 8.52 ± 0.32. For texture, the control scored 8.18 ± 0.35, while T_1, T_2, and T_3 scored 8.82 ± 0.24, 8.40 ± 0.33, and 8.60 ± 0.30 respectively. Finally, the overall acceptability scores were 8.26 ± 0.31 for the control, 8.94 ± 0.20 for T_1, 8.48 ± 0.28 for T_2, and 8.70 ± 0.25 for T_3. Overall, all treatment muffins showed higher sensory scores compared to the control, with T_1 consistently achieving the highest values across all attributes, indicating that the addition of flaxseed and strawberry powders improved the sensory qualities of the muffins.

The sensory analysis results of muffins enriched with flaxseed powder and strawberry powder, as presented in Table 3, demonstrate a clear enhancement in sensory attributes compared to the control sample. Each attribute colour, flavour, taste, texture, and overall acceptability — showed higher mean scores in the treatment groups T_1, T_2, and T_3 than in the control, signifying an improved sensory quality with the incorporation of these ingredients.

Specifically, the colour scores increased from 8.12 ± 0.42 in the control to 8.76 ± 0.28 in T_1, with T_2 and T_3 also showing elevated scores at 8.34 ± 0.38 and 8.58 ± 0.31 respectively. This suggests that the addition of flaxseed and strawberry powders positively influenced the visual appeal of the muffins. This aligns with findings from other studies where the incorporation of plant-based powders and functional ingredients improved muffin colour and consumer perception (Topaloğlu Günan & Yolci Ömeroğlu, 2025; Tukassar et al., 2023).

For flavour, the control muffin's score of 8.04 ± 0.36 was surpassed by T_1 scoring 8.68 ± 0.25, with T_2 and T_3 having intermediate but still enhanced values (8.28 ± 0.34 and 8.46 ± 0.29). This increase in flavour acceptability can be attributed to the aromatic and taste profiles contributed by flaxseed and strawberry powders, which have been documented to enhance flavor in functional bakery products (Mousavi et al., 2019).

Taste scores followed a similar pattern: the control scored 8.10 ± 0.40, while T_1 was the highest at 8.74 ± 0.27. Treatments T_2 and T_3 also scored well above control at 8.30 ± 0.36 and 8.52 ± 0.32. The consistent improvement in taste may be due to the combined effect of natural sweetness and nutty notes introduced by the added powders, which is supported by observations in muffins enriched with other dietary fibers and healthy ingredients (Heo et al., 2019; Lončar et al., 2022).

Texture scores increased from 8.18 ± 0.35 in the control to 8.82 ± 0.24 in T_1, with T_2 and T_3 also showing notable improvements. Improved texture is frequently observed in muffins where flaxseed is incorporated, as flaxseed gel or powder contributes to moisture retention and structural cohesion (Mousavi et al., 2019; Topaloğlu Günan & Yolci Ömeroğlu, 2025). This enhancement results in a softer, more palatable crumb, which is preferred by consumers.

Overall acceptability scores reflect the cumulative impact of all these sensory characteristics, with control at 8.26 ± 0.31 and treatments rising up to 8.94 ± 0.20 in T_1. This trend confirms that these ingredient additions meaningfully improve the consumer-perceived quality of muffins. High overall acceptability is critical to the success of functional or enriched bakery items, and

studies have shown that inclusion of fibers, seeds, and fruit powders can increase the health appeal without compromising sensory qualities (Ortega-Heras et al., 2019; Tukassar et al., 2023).

In summation, the sensory evaluation indicates that muffins supplemented with flaxseed and strawberry powders, particularly in formulation T_1, outperform the control across all sensory parameters. These findings confirm that such enrichment not only supports nutritional enhancement but also delivers superior sensory quality, reinforcing their promising application in healthier bakery product development. The consistent pattern of improvement across colour, flavour, taste, texture, and overall acceptability validates the positive role of flaxseed and strawberry powders in improving muffin sensory profiles

The results indicate that the incorporation of flaxseed powder and strawberry powder positively influenced the sensory attributes of the muffins. Among the treatments, T_1 exhibited the highest scores for all evaluated parameters, demonstrating enhanced colour, flavour, taste, texture, and overall acceptability compared to the control. This suggests that the addition of these powders can improve the sensory quality of muffins, making them more appealing to consumers.

Table 4 Proximate composition of developed muffins using flaxseed powder and strawberry powder

S.No	Variables	Control	T_1	T_2	T_3
1	Colour	8.12 ± 0.42	8.76 ± 0.28	8.34 ± 0.38	8.58 ± 0.31
2	Flavour	8.04 ± 0.36	8.68 ± 0.25	8.28 ± 0.34	8.46 ± 0.29
3	Taste	8.10 ± 0.40	8.74 ± 0.27	8.30 ± 0.36	8.52 ± 0.32
4	Texture	8.18 ± 0.35	8.82 ± 0.24	8.40 ± 0.33	8.60 ± 0.30
5	Overall acceptability	8.26 ± 0.31	8.94 ± 0.20	8.48 ± 0.28	8.70 ± 0.25

The proximate composition of developed muffins using flaxseed powder and strawberry powder showed the following values: Colour was 8.12 ± 0.42 for the Control, 8.76 ± 0.28 for T_1, 8.34 ± 0.38 for T_2, and 8.58 ± 0.31 for T_3; Flavour was 8.04 ± 0.36 for the Control, 8.68 ± 0.25 for T_1, 8.28 ± 0.34 for T_2, and 8.46 ± 0.29 for T_3; Taste was 8.10 ± 0.40 for the Control, 8.74 ± 0.27 for T_1, 8.30 ± 0.36 for T_2, and 8.52 ± 0.32 for T_3; Texture was 8.18 ± 0.35 for the Control, 8.82 ± 0.24 for T_1, 8.40 ± 0.33 for T_2, and 8.60 ± 0.30 for T_3; and Overall acceptability was 8.26 ± 0.31 for the Control, 8.94 ± 0.20 for T_1, 8.48 ± 0.28 for T_2, and 8.70 ± 0.25 for T_3.

Table 5 Color properties of developed muffins

Color	Control	T_1	T_2	T_3
L*	41.24 ± 0.18	40.12 ± 0.21	39.04 ± 0.19	37.86 ± 0.22
a*	7.42 ± 0.04	8.36 ± 0.06	9.18 ± 0.08	10.24 ± 0.10
b*	18.14 ± 0.21	19.26 ± 0.28	20.44 ± 0.32	21.58 ± 0.36

Values are expressed as Mean ± SD

The table presents the color properties of developed muffins across four groups: Control, T_1, T_2, and T_3. The L* value, indicating lightness, decreases progressively from 41.24 ± 0.18 in the Control group to 37.86 ± 0.22 in T_3, showing that muffins become darker with each treatment. The a* value, representing the red-green spectrum, increases from 7.42 ± 0.04 in Control to 10.24 ± 0.10 in T_3, indicating a shift toward a redder hue. Similarly, the b* value, which measures the yellow-blue spectrum, rises from 18.14 ± 0.21 in Control to 21.58 ± 0.36 in T_3, suggesting increased yellowness in the muffins as treatments progress. All values are expressed as mean ± standard deviation.*

Texture profile analysis of developed muffins using flaxseed powder and strawberry powder

Table 6 Texture profile analysis of developed muffins using flaxseed powder and strawberry powder

Textural Parameters	Control	T_1	T_2	T_3
Hardness (N)	4.12 ± 0.11	4.48 ± 0.14	4.92 ± 0.18	5.36 ± 0.21
Chewiness (J)	2.42 ± 0.08	2.84 ± 0.10	3.18 ± 0.12	3.54 ± 0.16
Springiness (m)	0.82 ± 0.03	0.86 ± 0.04	0.90 ± 0.05	0.94 ± 0.06
Gumminess (N)	3.18 ± 0.12	3.54 ± 0.14	3.92 ± 0.16	4.28 ± 0.19

Values are expressed as Mean ± SD

The last developed muffins that were fortified with flaxseed powder and strawberry powder displayed positive morphological and sensory qualities. The product had soft texture, crust formation was even, appealing colour and acceptable volume expansion after baking. Higher concentration of flaxseed powder gave a somewhat darker crumb colour because of its natural colouring and strawberry powder increased aesthetic appeal and flavour base of the muffins (National Institute of Nutrition (NIN), 2023). The muffins had homogeneous distribution of pores and good aeration but not too hard or crumbly. The optimized muffin formulation had the best overall appearance, texture and consumer acceptability when subjected to sensory evaluation studies and product assessment studies.

According to the statistical analysis of sensory scores there were significant differences between the control and treatment samples in terms of color flavor and overall acceptability ($p < 0.05$). This suggests that the addition of strawberry powder had a discernible effect on both taste and appearance. Similar to this the proximate composition analysis revealed a notable increase in crude fiber and protein content demonstrating that the addition of flaxseed improved nutritional value (Tulipani et al., 2009). The modified formulations health benefits were supported by the statistically significant decrease in fat content. On the other hand factors like texture and moisture content varied comparatively less suggesting that the addition of functional ingredients had little effect on the muffins structural quality.

Conclusion

This study was designed to develop the muffins using flax seeds and strawberry powder. The developed muffins were subjected for sensory analysis, proximate composition and texture profile analysis and also determined the color properties of the developed muffins. The results indicated that the flaxseed powder is notably higher in protein, fat, dietary fibre, and energy content compared to strawberry powder. Conversely, strawberry powder contains significantly more carbohydrates, total sugars, and vitamin C. These compositional differences highlight the distinct nutritional profiles of the two powders, which could influence their functional applications in food products**.**

The proximate composition of flaxseed powder and strawberry powder per 100 grams is as follows: flaxseed powder contains 28.90 grams of carbohydrates, 1.60 grams of total sugars, 6.50 grams of moisture, 18.30 grams of protein, 42.20 grams of fat, 27.30 grams of dietary fibre, 3.40 grams of ash, 0.60 milligrams of vitamin C, and provides 534.00 kilocalories of energy. In comparison, strawberry powder contains 74.50 grams of carbohydrates, 58.2 grams of total sugars, 5.80 grams of moisture, 7.20 grams of protein, 1.10 grams of fat, 14.60 grams of dietary fibre, 2.80 grams of ash, 52.40 milligrams of vitamin C, and provides 356.00 kilocalories of energy per 100 grams.

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