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Physicochemical characterization of mulberry-supplemented muffins

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Abstract
The race of life and fast-food eating habits trickled down the health status and created chronic ailments. The trend of cooking at home and eating healthy fruits and vegetables is becoming scarce. These circumstances are creating health issues in children because the parents are unable to care for them. The proximate analysis of mulberry powder was conducted and muffins were prepared with 5, 10, 15, 20, and 25% supplementation of mulberry powder. The quality parameters, i.e., water activity, color, texture analysis (hardness, firmness, and gumminess), pH, and sensory analysis, were evaluated. The results depicted that the highest pH decrease was observed in T_4 (5.72±0.03) and T_5 (5.61±0.02) with the increase in mulberry powder concentrations which remained low throughout the study period. The water activity (a_w) was increased in T_3 and T_4 but T_5 showed at par values to the T_4 resulting non-significant increase in a_w. The L*, a* and b* values exhibited that the T_3 and T_4 showed the least color changes as compared to other supplemented muffins. The hardness, firmness, gumminess, and sensory analysis were also improved in mulberry powder-supplemented muffins. It was concluded from the results that the mulberry powder supplementation in muffins enhanced not only shelf life but also improved the quality attributes of muffins.

Keywords: mulberry powder, muffins, shelf life, quality parameters, physiochemical characteristics

Introduction
The development of cosmopolitan cities and the industrial revolution promoted the trends of processed foods because of the busy lifestyle and ease of access. These factors contributed to compromised health status and chronic illness [27]. Regulatory authorities and monitory agencies took steps to overcome huge economical losses due to hospitalization and create awareness [5]. The advancement in knowledge explored the health benefits of foods from plant sources and started a psychological move towards plant foods initiating the development of functional products.

Fruits are a rich source of phytochemicals and micro-minerals which are potentially bioactive in nature. These compounds influence a variety of bodily mechanisms and protect from stressors. Phytochemicals like polyphenols, tocopherols, anthocyanins, carotenoids, terpenoids, and alkaloids have anti-inflammatory, anti-cancer, and antioxidants properties and prevent several metabolic disorders i.e., cataracts, cancer, diabetes, stroke, cardiovascular and Alzheimer's disease [29]. *Morus alba* belongs to the family *Moraceae* with approximately 100 edible species in the genus. *Morus* is widely grown for the purpose of silk production in Asia, Europe, and America but its fruit is rich in anthocyanins which are strong antioxidants and protect the body from free radical-mediated metabolic disorders [6].

The *Morus* species which are deep in color are a good source of flavonoids, anthocyanins, and carotenoids, mostly grown in Europe while white-colored varieties are mostly found in northern India, Iran, and Pakistan [15]. In Turkey, mulberry serves a medicinal function and is used to treat mouth lesions due to the presence of anthocyanins. These phytochemicals also play a vital role in the production of thromboxanes, prostaglandins, and leukotrienes [25]. Mulberry fruit has the ability to regulate and promote physical functions like inflammatory responses, blood viscosity, and the immune system. The polyunsaturated fatty acids which are derivatives of linoleic acid and linolenic acid present in the fruit are responsible for the structural integrity of the cell membrane and also provide stability to the cellular components [31].

In the food industry, mulberry is widely used as a supplement to enhance the functional properties of food and to promote the health of the consumer. Mostly in dried form in fruit juices, liquors, marmalades, James, and jellies as a natural coloring ingredient, and also in the cosmetic industry[37]. Among all barriers, it has exceptional nutritional value, rich in fructose which is essential for sperm health and motility. Mulberry juice is widely used to cure throat infections and fever. In the winter season, dried mulberries are consumed along with other dry fruits to promote health effects [8]. It is used in different traditional recipes such as puddings, tarts, pies, syrups, sauces, and ice cream. Confections also use mulberry for improving the taste and nutritional quality of their products. In countries like Thailand, Japan, and China mulberry tea is used as a health drink to lower blood cholesterol and post-prandial glucose level [7].

Muffins are popular baked items used as snack foods made from wheat flour. These products are also used as breakfast cereals, are most, and are loaded with fat fractions. The study was designed to develop mulberry-supplemented muffins and the evaluation of different physicochemical and textural changes takes place due to the addition of mulberry powder. The purpose of this study was to promote healthy snacking which ultimately enhanced the quality of life of the target groups i.e., school-going children.

Material and Methods

Procurement of raw material

The fresh black mulberries were harvested from the local areas of Multan city. The collected fruit was washed properly and dried using the vacuum drier at a lower temperature i.e., 50ºC. The dried sample was then converted into powder form by a mechanical grinder (WF-9227). After sieving the sample was placed in a glass jar and kept at a lower temperature in dark for supplementation in muffins and further analysis. Other ingredients used in muffins were purchased from the local market of Multan, Punjab Pakistan.

Proximate estimation

The proximate composition of the collected sample was done following the procedures given in [2]. The components like protein, fat, moisture, ash, dietary fiber and mineral were recorded in percentiles.

Preparation of mulberry-supplemented muffins

A general procedure for muffin preparation was followed i.e., the batter was prepared by mixing sugar and butter using a mechanical Dough mixer (BD-5L, Guangzhou Bossda Mechanical Equipment Co., Ltd). After properly beating the flour and eggs were added along with the mulberry powder and mixed till white creamy batter. The batter was filled in 40g muffin paper after placing it in a moulding tray. The trays were placed in a preheated baking own at 180-200ºC for about 20 minutes. At the completion of baking, the prepared muffins were cooled at room temperature and properly packed, and kept for further analysis. The treatment plan designed for the study is given in Tab 1.

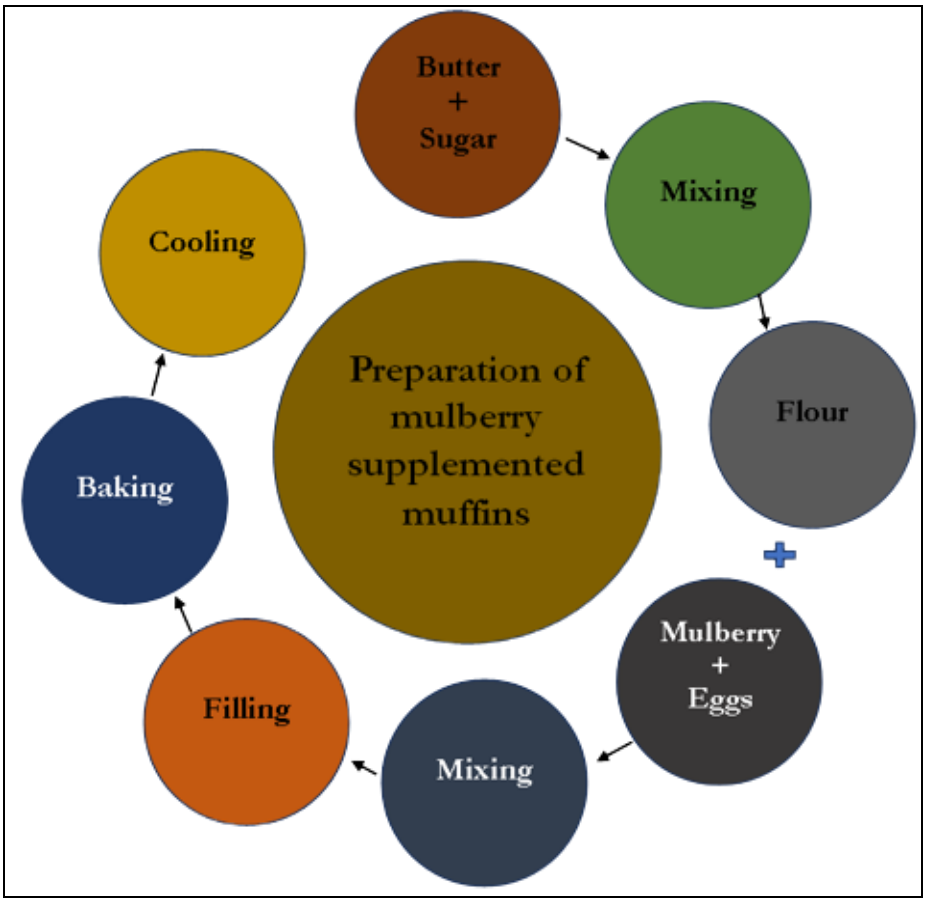

Fig 1: Flow diagram for preparation of mulberry-supplemented muffins

Table 1 Treatment plan of supplementation

Treatments	Wheat Flour %	Mulberry Powder %
T_0	100	-
T_1	95	5
T_2	90	10
T_3	85	15
T_4	80	20
T_5	75	25

The water activity of mulberry-supplemented muffins

Mulberry-supplemented muffins were tested for water activity at different storage levels by using Lab Swift a_w Activity Meter 3012-80 as evaluated by [22].

Color of mulberry-supplemented muffins

The instrumental color of the supplemented muffins was done by using a Minolta Chroma meter as per the procedure followed by [33]. Readings were taken in triplicates and colors were noted as L* = lightness, a* = red, and b* yellow.

Texture analysis of mulberry-supplemented muffins

Textural characteristics of muffins i.e., Hardness, firmness, and gumminess were evaluated by using a texture analyzer (TA-XT2, Stable microsystem Surrey, England) with features i.e., 36mm long cylindrical probe, a diameter of 8mm and 0.5mm/sec penetrating speed [28].

The pH of mulberry-supplemented muffins

The pH of the sample was conducted by using a digital pH meter (PH-2005) by dipping the electrode in the already prepared solution. To prepare the solution 5g of the sample was taken in a beaker in which 30ml of distilled water was added followed by shaking at 200rpm for 10 minutes [14].

Sensory evaluation of mulberry-supplemented muffins

The sensory characteristics of the muffins supplemented with mulberry powder were evaluated by expert panelists of the Institute of Food Science and Nutrition, Bahauddin Zakariya University. The sensory scores were noted by using a 9-point scale [23].

Statistical analysis

The data reported from different investigations were tested for the level of significance by using the statistical software (Statistics 8.1) applying CRD [32].

Results And Discussion

Proximate composition of the mulberry powder

The proximate composition of mulberry powder given in the Tab 2 showed that mulberry fruit has maximum contents of dietary fiber i.e., 11.36%, and low fat. The fruit also contained lower amounts of minerals and proteins.

Table 2 Proximate composition of mulberry powder (%)

Content	Quantity (%)
Moisture	16.71
Fat	0.40
Protein	0.97
Dietary Fiber	11.36
Ash	0.51

The pH of mulberry powder-supplemented muffins

The pH of any food system is an indication of product stability. It varies with the change in respiration and microbial activities. When baked products are stored, the breakdown of carbohydrates occurs at a very low-level producing change in pH. The pH of mulberry-supplemented muffins showed a highly significant difference among the treatments while the trend along storage days was less prominent. The T_2 sample yielded best with a pH of 6.55±0.04 at 0 days and reduced to 7.1±0.03 on the 28th day of storage as shown in Tab 3. pH decreased with the addition of mulberry powder and was 5.61±0.02 in T_5 at the initial level of storage and 5.53±0.4 at the end. Among the treatments, T_2 was best followed by T_1, T_3, and T_4. The results were similar to the findings of [18] who replaced sugar with jaggery. Another study by [1] reported the pH of mulberry-supplemented muffins i.e., 6.76 which was close to the results given in the study. The minor changes in pH might be due to the fluctuations in environmental temperature and humidity which can bring compositional changes.

Table 3: Effect of mulberry powder supplementation on the pH of muffins during the storage period

Treatments	Storage days				
	0	7	14	21	28
T_0	7.3±0.02^{a}	7.23±0.02^{b}	7.17±0.03^{c}	7.15±0.02^{c}	7.1±0.03^{d}
T_1	6.97±0.07^{e}	6.88±0.05^{f}	6.76±0.04^{g}	6.69±0.02^{h}	6.63±0.03^{h}
T_2	6.55±0.04^{i}	6.45±0.02^{j}	6.4±0.02^{k}	6.32±0.01^{l}	6.82±0.02^{m}
T_3	6.23±0.02^{n}	6.15±0.02^{o}	6.12±0.01^{o}	6.06±0.03^{p}	6.67±0.02^{p}
T_4	5.72±0.03^{t}	5.81±0.02^{s}	5.85±0.02^{rs}	5.89±0.02^{qr}	5.93±0.02^{q}
T_5	5.61±0.02^{u}	5.59±0.01^{uv}	5.57±0.01^{uv}	5.56±0.01^{vw}	5.53±0.4^{w}

T0 = control sample, T1 = 5% mulberry powder, T2 = 10% mulberry powder, T3 = 15% mulberry powder, T4 = 20% mulberry powder, T5 = 25% mulberry powder

The water activity of mulberry powder-supplemented muffins

Water activity (a_w) is the ratio of the vapor pressure of food to the vapor pressure of pure water and is a determinant of food spoilage. Muffins are semi-perishable foods with an a_w range of 0.50–0.80. The results regarding a_w of mulberry-supplemented muffins are given in Table 4 indicating that there was a slight significant effect on a_w through the storage period. The a_w of a sample containing 5% of mulberry powder was 0.59±0.05 at an initial level which slightly increased to 0.61±0.02 and this variability was linked with storage conditions. The best treatment was T_2 in which water activity varied from 0.56±0.02 to 0.57±0.03 as shown in Table 3. The increased a_w level of T_3, T_4, and T_5 were due to the presence of more mulberry powder. The periodically tested results of the study showed an increase in a_w and were aligned with the finding of [16] and [20].

Table 4 Effect of mulberry powder supplementation on the water activity of muffins during the storage period

Treatments		Storage days			
	0	7	14	21	28
T_0	0.56±0.03^{r}	0.55±0.03^{ozp}	0.57±0.05^{klm}	0.56±0.03^{defg}	0.59±0.03^{bcd}
T_1	0.59±0.05^{q}	0.61±0.04^{mno}	0.57±0.03^{ijkl}	0.59±0.05^{fghi}	0.61±0.02^{ab}
T_2	0.56±0.02^{r}	0.55±0.01^{q}	0.57±0.04^{op}	0.59±0.04^{jkl}	0.57±0.03^{defg}
T_3	0.64±0.01^{p}	0.63±0.02^{nop}	0.60±0.01^{ghij}	0.61±0.02^{def}	0.63±0.04^{bc}
T_4	0.65±0.03^{lmn}	0.67±0.02^{hijk}	0.62±0.03^{efgh}	0.64±0.03^{cde}	0.67±0.05^{bc}
T_5	0.65±0.02^{klm}	0.68±0.03^{fghi}	0.64±0.02^{efgh}	0.66±0.02^{bc}	0.68±0.03^{a}

T0 = control sample, T1 = 5% mulberry powder, T2 = 10% mulberry powder, T3 = 15% mulberry powder, T4 = 20% mulberry powder, T5 = 25% mulberry powder

The instrumental color of mulberry supplemented muffins

The color of products is a key element due to their appealing and attractive attributes. Therefore, the color of the prepared muffins was analyzed on weekly basis through the Minolta Chroma meter. The L* value was observed highest in control (T_0) exhibiting the lightest color of muffins but darkened with the addition of mulberry powdered. The lowest L value (darkest) for color was observed in T_5 containing the highest percentiles of Mulberry powder. The lightness of the samples decreased with the passage of time and the darkening in all muffins was observed on the 28th day of study as shown in Tab 5. The a* value represents the color from greenness to redness color. The lowest a* value was observed in the T_0 group and the highest was observed in the T_5 group showing that the redness of the color of samples was increased with the increase in the concentration of a mulberry powder. A similar increase in all groups was observed on the 28th day of the storage study. The b* value showed the blueness of the yellowness of the sample color. b* value was highest in T_0 and lowest in the T_3 group. The decrease in the b* value was observed in all groups but T_4 showed an increase in the b* value (19.97±0.9 to 27.37±0.93).

The results of the current study were comparable with the findings of [17]. Who reported L, a*, and b* values as ranging from 66.00±0.56 to 69.87±1.19, 7.99±0.67 to 10.95±0.35 and 29.12±1.36 to 32.46±0.21, accordingly when different components were added in muffins.

Table 5: Effect of mulberry powder supplementation on instrumental color values of muffins during the storage period

Parameter	Treatments	Storage days				
		0	7	14	21	28
L*	T_0	$76.08±0.47^{a}$	$75.91±0.64^{b}$	$74.8±0.57^{c}$	$72.74±0.39^{d}$	$72.31±0.28^{e}$
	T_1	$57.22±0.62^{f}$	$56.16±0.03^{g}$	$55.32±0.18^{h}$	$54.44±0.44^{i}$	$52.3±0.13^{j}$
	T_2	$52.4±0.41^{j}$	$50.32±0.19^{k}$	$48.34±0.21^{l}$	$47.59±0.26^{m}$	$46.51±0.3^{n}$
	T_3	$42.52±0.26^{o}$	$40.42±0.26^{p}$	$37.3±0.07^{q}$	$35.43±0.15^{r}$	$34.39±0.18^{s}$
	T_4	$41.53±0.11^{p}$	$40.36±0.19^{q}$	$39.26±0.19^{r}$	$35.4±0.25^{s}$	$31.43±0.31^{t}$
	T_5	$37.9±0.52^{nd}$	$34.49±0.18^{u}$	$33.42±0.34^{v}$	$30.61±0.26^{w}$	$27.5±0.45^{x}$
a*	T_0	$7.59±0.22^{o}$	$8.74±0.25^{no}$	$9.38±0.17^{mno}$	$10.39±0.17^{k-n}$	$11.68±0.17^{ijk}$
	T_1	$9.21±0.11^{mno}$	$10.63±0.17^{klm}$	$11.7±0.36^{ijk}$	$12.55±0.38^{hij}$	$13.457±0.38^{ghi}$
	T_2	$11.42±0.1^{jkl}$	$12.58±0.38^{hij}$	$9.7±6.06^{lmn}$	$14.55±0.01^{fg}$	$13±0.18^{def}$
	T_3	$12.8±0.93^{ghij}$	$13.59±0.35^{fgh}$	$14.4±0.18^{fgh}$	$15.36±0.13^{def}$	$13.46±0.39^{cd}$
	T_4	$14.56±0.27^{efg}$	$15.43±0.44^{ac}$	$16.59±0.4^{cd}$	$17.65±0.32^{bc}$	$18.2±0.08^{bc}$
	T_5	$16.44±0.19^{cde}$	$17.52±0.36^{bc}$	$18.29±0.13^{bc}$	$19.09±0.71^{ab}$	$20.22±0.3^{a}$
b*	T_0	$43.22±0.17^{a}$	$43.02±0.12^{a}$	$42.69±0.53^{ab}$	$42.05±0.15^{ab}$	$41.39±0.16^{b}$
	T_1	$29.51±1.16^{cd}$	$29.22±1.05^{cde}$	$28.65±0.67^{c-f}$	$27.91±0.82^{efg}$	$27.37±0.58^{fg}$
	T_2	$29.64±1.36^{c}$	$29.4±1.51^{cd}$	$28.87±1.4^{cde}$	$28.18±1.5^{d-g}$	$27.18±1.04^{g}$
	T_3	$19.97±0.9^{mno}$	$19.3±0.78^{no}$	$18.7±0.88^{op}$	$17.56±0.73^{pq}$	$17.37±0.93^{q}$
	T_4	$24.18±0.51^{h}$	$23.45±0.48^{hi}$	$22.83±0.49^{hij}$	$22.04±0.46^{ijk}$	$21.16±0.65^{klm}$
	T_5	$23.34±0.77^{hi}$	$22.69±0.86^{ij}$	$21.86±1.12^{jkl}$	$20.55±1.06^{lmn}$	$19.91±1.06^{mno}$

T0 = control sample, T1 = 5% mulberry powder, T2 = 10% mulberry powder, T3 = 15% mulberry powder, T4 = 20% mulberry powder, T5 = 25% mulberry powder

Effect on Hardness, Firmness, and Gumminess of mulberry powder supplemented muffins

The hardness, firmness, and gumminess of the muffin were measured during the storage period of 0-28 days to evaluate their quality attributes. The maximum values of hardness were observed in T_0 (13.51±0.02 N) and the least observed in T_5 (12.35±0.02 N). The results showed that the increase in the concentration of mulberry powder enhanced the softness of the muffins. The hardness of the muffins increased after 28 days in all groups leading to the deterioration of the muffins. The increase in hardness was due to the loss of moisture and decline in air cells of the muffins and the mulberry powder proved to attain higher concentrations of moisture in the muffins [24]. The firmness of the muffins was determined to measure the resistant force required to deform the texture of the muffins. The highest value of firmness was observed in the control group (T_0) which decreased with the increase in the concentration of mulberry powder in muffins. The weekly evaluation showed almost a similar trend and at the end of the study period (on the 28th day), the Muffins containing 25% mulberry powder showed a firmness value resulting in the least moisture loss during the storage period. The stickiness and cohesiveness of the muffins were evaluated by measuring the gumminess attributes through a texture analyzer.

The current study showed that the addition of mulberry powder in small concentrations (5 and 10%) decreased the gumminess of muffins and further increased in concentrations (15 and 20%) showed almost similar values to the control and the 25% mulberry powder enhanced the gumminess of muffins significantly. The highest increase (~100%) of gumminess was observed in T_0 followed by T_5, T_4, T_3, T_1, and T_2 (Tab 6). These attributes were also interlinked with the moisture loss of the muffins. The mulberry powder contained good concentrations of gums which have the ability to bind water [12]. The variations in the gumminess of muffins were also dependent on chemical reactions taking place inside the muffins due to environmental variations [30]. The gumminess values of muffins observed by [36] were incoherent with the current study. It was reported that the 173.08±27.56 Nm^2 at 0% addition of perilla and 161.61±17.91 Nm^2 with 9% addition of perilla.

Table 6: Effect of mulberry powder supplementation on hardness, firmness, and gumminess of muffins during the storage period

Parameter	Treatment	Storage days				
		0	7	14	21	28
Hardness (N)	T_0	13.51 ± 0.02^{f}	13.58 ± 0.04^{e}	13.76 ± 0.02^{c}	13.86 ± 0.04^{b}	14.05 ± 0.02^{a}
	T_1	13.30 ± 0.01^{h}	13.40 ± 0.02^{g}	13.49 ± 0.03^{f}	13.68 ± 0.04^{d}	13.73 ± 0.01^{c}
	T_2	12.46 ± 0.03^{rst}	12.57 ± 0.02^{op}	12.68 ± 0.0^{mn}	12.79 ± 0.02^{l}	12.93 ± 0.04^{j}
	T_3	12.71 ± 0.03^{m}	12.78 ± 0.02^{l}	12.84 ± 0.03^{k}	12.89 ± 0.04^{j}	12.98 ± 0.01^{i}
	T_4	12.38 ± 0.01^{uv}	12.44 ± 0.02^{nd}	12.50 ± 0.04^{qr}	12.56 ± 0.01^{op}	12.64 ± 0.02^{n}
	T_5	12.35 ± 0.02^{v}	12.42 ± 0.03^{tu}	12.48 ± 0.02^{rs}	12.53 ± 0.03^{pq}	12.48 ± 0.04^{o}
Firmness (N)	T_0	138.33 ± 0.02^{q}	194.33 ± 0.02^{l}	255.33 ± 0.03^{h}	310.00 ± 0.01^{c}	374.00 ± 0.01^{a}
	T_1	127.33 ± 0.01^{r}	175.67 ± 0.02^{n}	234.33 ± 0.01^{j}	283.00 ± 0.04^{e}	329.67 ± 0.02^{b}
	T_2	113.67 ± 0.02^{s}	158.00 ± 0.02^{o}	216.67 ± 0.02^{k}	275.00 ± 0.01^{f}	309.67 ± 0.01^{c}
	T_3	103.33 ± 0.03^{t}	151.33 ± 0.01^{p}	194.67 ± 0.04^{l}	239.00 ± 0.01^{i}	298.33 ± 0.03^{d}
	T_4	93.00 ± 0.02^{u}	141.33 ± 0.02^{q}	182.67 ± 0.01^{m}	233.00 ± 0.01^{j}	286.00 ± 0.03^{e}
	T_5	83.67 ± 0.04^{v}	129.33 ± 0.01^{r}	173.00 ± 0.02^{n}	215.67 ± 0.0^{k}	264.00 ± 0.01^{g}
Gumminess (Nm^2)	T_0	106.67 ± 0.01^{r}	224.00 ± 0.03^{a}	216.67 ± 0.04^{b}	208.00 ± 0.01^{c}	203.67 ± 0.02^{d}
	T_1	96.33 ± 0.31^{t}	196.33 ± 0.01^{e}	185.67 ± 0.01^{g}	181.67 ± 0.02^{h}	176.67 ± 0.02^{i}
	T_2	97.00 ± 0.02^{t}	190.00 ± 0.01^{f}	181.33 ± 0.02^{h}	174.00 ± 0.02^{jk}	172.00 ± 0.01^{kl}
	T_3	102.00 ± 0.03^{s}	184.00 ± 0.01^{g}	175.00 ± 0.02^{ij}	171.33 ± 0.01^{l}	167.00 ± 0.02^{m}
	T_4	108.33 ± 0.04^{r}	176.67 ± 0.03^{i}	171.33 ± 0.02^{l}	166.33 ± 0.01^{m}	162.00 ± 0.02^{n}
	T_5	115.00 ± 0.02^{q}	170.67 ± 0.02^{l}	165.33 ± 0.04^{m}	159.33 ± 0.04^{o}	154.33 ± 0.02^{p}

T_0 = control sample, T_1 = 5% mulberry powder, T_2 = 10% mulberry powder, T_3 = 15% mulberry powder, T_4 = 20% mulberry powder, T_5 = 25% mulberry powder

Sensory analysis of mulberry powder-supplemented muffins

When the sensory score by the panelist was evaluated, the results indicated that the sensory color of mulberry-supplemented muffins decreased with the passage of time. It is obvious from figure 2A that T_2 yielded the best and was liked by the panelists. The comparison of treatments with the control sample showed that the sensory color of T_5 was less prominent followed by T_4 and T_3. The gradual decrease in the sensory color of the mulberry powder-supplemented muffins might be due to the temperature fluctuations during storage which degraded the anthocyanins contents present in the mulberry powder. [10]. also indicated that the sensory color of muffins made from millet was decreased during storage and similar trends were reported by [19].

Taste is an indicator of palatability and is mostly perceived by the consumer. Taste influences the overall acceptability of the product. Results regarding the sensory taste of the mulberry-supplemented muffins showed that there was no observable change in the taste of mulberry powder-supplanted muffins. But, with the increase in storage days, the taste slightly changed in treatments where the mulberry powder was in higher concentrations. The adverse change was in the order of $T_5>T_4>T_3$ as shown in figure 2B. The 10% mulberry powder-containing treatment was best when compared with the control and other treatments. The results were according to the findings of [13]. [3] Also found a similar but slower decline in the taste of the product.

During the storage period of 28 days, the effect of mulberry powder concentration was highly significant on the mouthfeel of mulberry powder-supplemented muffins. Figure 2C clearly explained that the addition of more powder is responsible for the change in the texture of the product which adversely affects the mouthfeel. In T_5 there observed a more decline in the mouthfeel was by the sensory panelist but not to a rejection region. The T_2 showed the best results when compared with the control and other treatments. The reduction in the mouthfeel of the product showed a correlation with the findings of [21].

The sensory texture of the product reported by the panelist indicated that T_2 was the best treatment among all. The effect of storage was less prominent as compared to the effect of treatments. The higher concentrations of the powder were negatively correlated with the textural properties of the mulberry powder-supplemented muffins. The decrease in the texture of the product was due to changes in temperature and relative humidity in the environment. The breakdown of sugars may be one of the contributing factors to the deteriorative changes in the texture of the product. T_5 was the most affect treatment than T_4 and T_3 as shown in figure 2D. Textural changes in the product are aligned with the results of [11]. [26] Working on potato peel powder showed that adverse textural changes occur in the product due to higher amounts of added powder.

The appearance of the mulberry powder-supplemented muffins changed during the storage period and variations were observed among the treatments. T_2 was the best treatment throughout the storage period. The change in appearance in T_3, T_4, and T_5 was due to the degradation of the anthocyanins present as shown in figure 2E. The variability was linked with the fluctuations in environmental conditions. [4] Suggested the reduced appearance with advancement in storage conditions due to the degradation of coloring compounds.

The sensory results reported by the panelist showed variability along the storage period. Figure 2F demonstrated that changes in mulberry powder concentrations influenced the overall acceptability of the product. The increased gumminess and chewiness of the product were due to the presence of gummy substances like sericin which are made up of glycoproteins that produced undesirable changes in the mulberry powder-supplemented muffins. The T_2 was reported best when compared to the control due to the presence of less powder as shown in figure 2. The higher powder concentrations made other treatments less acceptable to the panelists. The results of the study are in corroborate the findings of [35] and [9] also investigated similar trends.

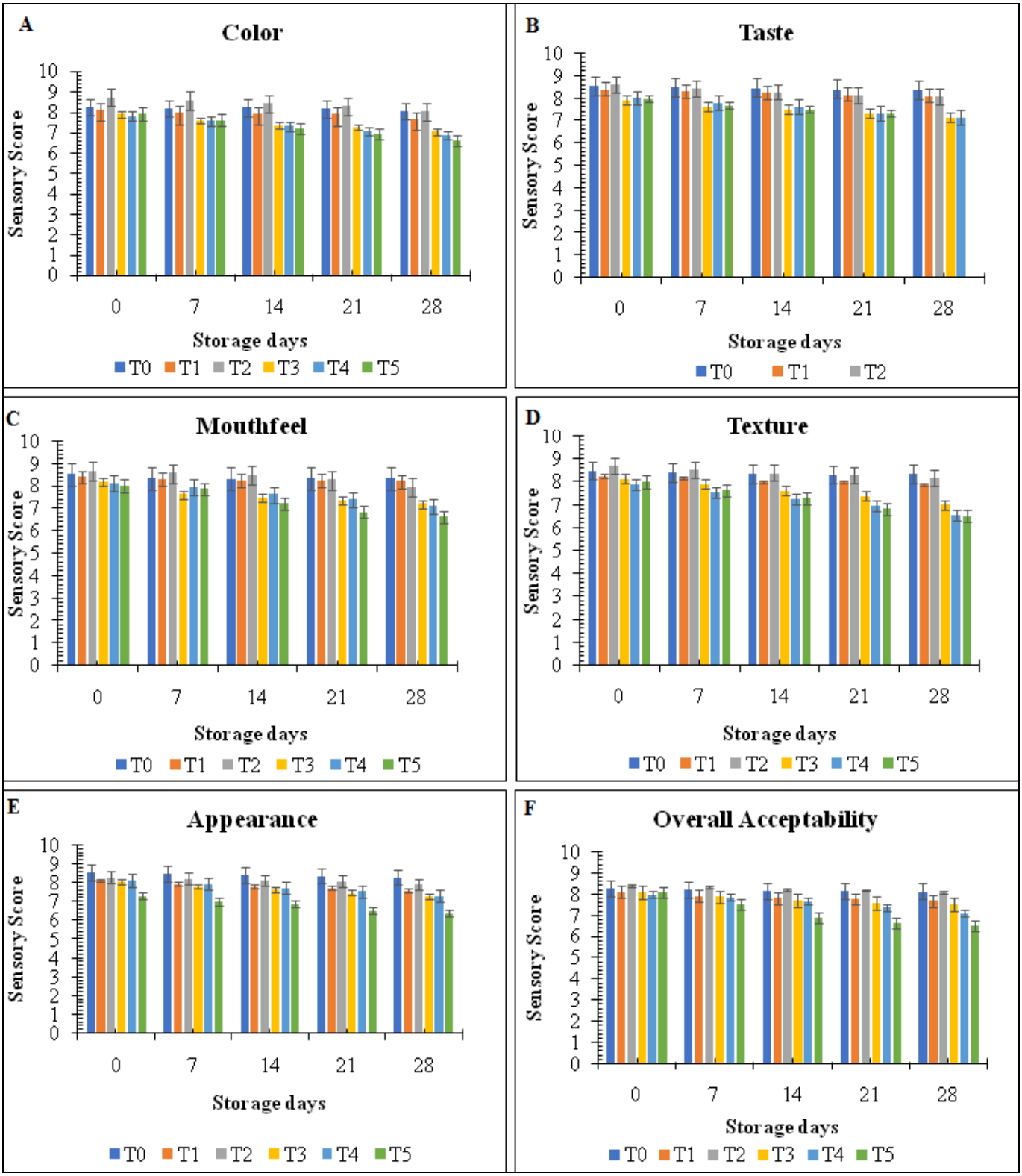

Fig 2: Effect of mulberry powder on sensory properties of muffins

Conclusion

It was concluded that the supplementation of mulberry powder was significant in the improvement of quality parameters and enhancement of the shelf life of muffins at all concentrations. However, T_3 and T_4 were considered best among all treatments as beyond T_4 negligible changes in muffins attributes were observed. Hence, the addition of mulberry powder can be proved significant from a technological point of view and nutritional improvement in muffins.

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