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Influence of Bioplastic and Synthetic Packaging Materials on Quality Stability of Wheat Flour During Storage at Atmospheric Condition

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ABSTRACT
This study was aimed to examine the effect of different packaging materials on physical and morphological characteristics of wheat flour during 90 days of storage was determined. The packaging material reduced the spoilage by providing moisture barrier, and maintained the water content of stored samples. Fresh wheat flour were packed using different packaging material such as bioplastic, polypropylene, and low density polyethylene and stored at room temperature (30±2℃). The properties such as colour, moisture, pH, and particle size distribution.The result of ΔE values demonstrated the least changes in BP (7.60) than the other PP (8.10), LDPE (9.82) at 90th day of storage. The moisture and pH of stored wheat flour were found in the range of 8.52 to 10.97 % and 6.29 to 7.03, respectively. Significant (p <0.05) changes were observed in to red wheat flour in different packaging materials and storage period. The particle size of wheat flour is related with the quality of wheat flour. Particle size span values of stored wheat flour ranges from 5.03 to 5.32 and control sample (37.17). The structural property of control and stored wheat flour sample was elucidated by scanning electron microscopy (SEM).
Keywords: packaging materials, bioplastic, wheat flour, moisture, storage period, particle size

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INTRODUCTION

Wheat flour (*Triticum aestivum*) is the most common raw material grown food crops in the world. Wheat flour consists of more amount of starches, which are known as polysaccharides. It also contains a significant quantity of vitamins like thiamine and vitamin B, as well as carbohydrates (78.10 %), protein (14.7 %), fat (2.10 %), minerals (2.10 %) [1]. It's difficult to store wheat flour in a suitable atmosphere and protect it from external elements [2].Wheat flour has a short shelf life due to insect infestation, contamination during packing, and environmental conditions that induce insect outbreaks [3].

The main purpose of packaging material is a moisture barrier, and keeping the water content of stored samples. Temperature and relative humidity are two significant elements that impact the moisture content of the flour, and the package's ability to avoid undesired moisture changes validates its appropriate packaging material for storing flours [4]**.** Polypropylene offers great rigidity/impact balance, remarkable fatigue resistance, superior chemical resistance, strong steam barrier, and other properties in addition to being low-cost and lightweight [5]. LDPE is a non-biodegradable thermoplastic film that is widely used for fresh commodity. Consumer items can be sealed, wrapped, and protected with polyethylene films. It has strong barrier properties, as well as resistance to oil and fat [6]. Alternative to conventional polymers based on petroleum is to produce new packaging materials using various biopolymers. Recent research in packaging materials focuses on converting non-biodegradable plastics to biodegradable films by incorporating biopolymers [7]. The CO_2 generated during the manufacturing, use, and disposal of plastics is balanced by CO_2 consumed during the plant's growth cycle, resulting in a significant reduction in the net carbon balance. Bioplastics development requires the use of less value raw materials, such as agricultural or food sector wastes, or non-edible genetically modified plants [8]. The physical and chemical characteristics of bioplastics have a vital role in their biodegradation and the organic compounds are broken down by microorganisms during biodegradation [[9]. During microorganisms totally convert fully biodegradable polymers to carbon dioxide, water, minerals, and biomass [10].

Storage period and temperature have an impact on quality of wheat, resulting in changes medications of the flour parameters. Moisture content plays an important role in the storage of wheat flour. The moisture level of flour has a significant impact on its shelf life; the lower the moisture content, the more stable the flour will be in storage. It was found that wheat flour samples with less than 10% moisture content showed minimum changes in the physico-chemical properties. Wheat gluten is directly connected to the quality of wheat flour [12]. Gluten is a kind of plastic-elastic protein component of wheat flour. The degree of extensibility and elasticity of gluten is a criterion for gluten quality [13].

Particle size is one of the important factors influencing the quality of wheat flour and the finished products. Unit operations such as milling, sieving, and superfine grinding can be employed to achieve desirable particle sizes [13]. However, the variety of wheat also influences the quality of wheat flour upon particle size. Particle size affects the bulk density of food products and is a crucial factor that determines packaging materials and material handling during food processing [15].Hence, considering the importance of packaging materials and quality of wheat was to compare and determine the optical, physical, and morphological properties of wheat flour stored in three different packaging material at room temperature (RT) for 90 days of storage.

Material and Methods

Sample preparation

Different packaging materials such as bioplastic (BP), polypropylene (PP), and low density polyethylene (LDPE) were developed by using axial blown extrusion method. The thickness of the packaging materials was BP (55 µm), PP (75 µm), and LDPE (75 µm). The wheat grain were purchased from local market Natarajan & co, Thanjavur and ground in local mill. After cooling, the wheat flour was packed in different packaging material such as BP, PP, and LDPE then stored at room temperature for 90 days to evaluate its quality.

Properties of wheat flour

Colour

Colour of wheat flour was measured in CIE L*a*b* colour system using Hunter colorimeter (Colour Flex EZ). Colour values were recorded as L*-0 (black), L*-100 (white); a* (-a, greenness; +a, redness); and b* (-b, blueness; +b, yellowness).The tests were carried out on various randomly chosen positions on the surface of each sample. According to following equation (1), the total colour difference (ΔE) was determined between measurements taken before packaging of wheat flour samples and measurements taken during storage time to evaluate colour transition [16].

$$\Delta E^* = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \qquad (1)$$

L*, a*, and b* value was used to measure the whiteness index of the wheat flour sample using the following equation (2) (17).

$$Whiteness\ index = 100 - \sqrt{(100 - L)^2 + a^2 + b^2} \qquad (2)$$

Where, L^*,a^*,b^* – value of wheat flour sample colour components measured before packaging;
L ,a,b –value of wheat flour sample colour components measured after storage time.

Moisture

The moisture content of wheat flour samples was calculated according to the method described by(18). Each sample (5 g) was weighed into glass Petri dishes that had been washed, dried, and weighed. The dishes, along with their contents, were placed in a hot air oven for 3 hours at 105°C.After cooling in desiccators, the samples were weighed. This process was repeated until the weight remained constant [19]. Therefore, the percentage of moisture content was determined by using the following equation (3)

$$Moisture\ content\ (\%) = \frac{W_1 - W_2}{\mathrm{W}} \times 100 \qquad (3)$$

Where,
W_1 = Weight of sample in dish before drying, gm
W_2 = Weight of dried sample + dish after drying, gm
W = Weight of sample, gm

pH

The pH of the flour samples was measured by making a 10 % (w/v) suspension of each sample in 90 ml of distilled water and let it be for 30 min. The suspensions were thoroughly mixed and the pH was determined using a Microprocessor pH meter(Model: LT- 501) [20].

Particle size analysis

Particle size distribution for each sample was analysed using particle size analyser (Model: Nano Plus). Particle size distribution (d_{10}, d_{50} and d_{90}), and span values were calculated using the following equation (4) [21].

$$\text{Span value} = \frac{d_{90} - d_2}{d_{50}} \times 100 \qquad (4)$$

SEM analysis

The micro structural analysis of the wheat flours was carried out using a Scanning Electron Microscopy (SEM) (Model: VEGA3 TESCAN). Wheat flour samples were placed with double-sided adhesive tape on aluminium stubs and sputter-coated with 200A° of gold. A scanning electron microscope operated with accelerating voltage of 10kV was used for the measurements and the images were directly stored in the device (22).

Statistical analysis

The experimental data were statistically analyzed using IBM SPSS software (version 20). The result was expressed as means ± standard deviation. Analysis of general linear model (Univariate) was performed to determine significant differences between the means of physical,optical and rheological properties of wheat flour during storage. The means were separated using the Tukey multiple range test, and least significant differences (LSD) at $p<0.05$.

RESULTS AND DISCUSSION

The results of optical, physical, rheological and morphological properties of wheat flour stored in different packaging materials in room temperature for 90 days are presented below.

Quality of wheat flour during storage

Color values (L, a, & b)

The colour value of wheat flour (L*, a*, & b*) are presented in Table 1. From the table it was observed that the L*, a*, and b* values of wheat flour packedin BP, PP, and LDPE were 77.94, 78.07 and 77.99; 1.98, 2.03 and 2.00; and12.52, 12.62 and 12.31for control (0th day). The maximum L*, a*, and b*values were found to be BP(84.50), PP (87.20),LDPE (85.12);BP (2.21), PP (2.62), LDPE (2.24); and BP (16.00), PP (16.11), LDPE (15.55) on 90th day of storage. PP films are more transparency, which has effect on difference in colour values. This might be due to light transmittance in the packaging materials that affect the colour pigments of packaged food products (6).Generally, temperature and particle size impact the colour of flour (23). Ahmed, (2015) reported that at high temperatures, the colour values of stored wheat flour may increase due to the presence of ambient oxygen and food enzymes.Variation in b* among the samples has been ascribed to carbohydrate and protein levels, which play a role in the development of non-enzymatic browning (25). Kumar & Saini, (2016) found a similar trend in colour values (L*, a*, b*) for wheat flour L* (92.78), a* (2.10), and b* (9.79), respectively.

ΔE and whiteness index

Colour difference (ΔE) and whiteness index values of wheat flour packed in different packaging materials are depicted in Table 2. The ΔE values of wheat flour stored at room temperaturein different packaging materials were found as BP (1.90), PP (2.05), and LDPE (1.60),respectively.At the end of storage, the ΔE values were found increase in the BP (7.60), PP (8.10), & LDPE (9.82). From the study, it is observed that the whiteness index of the wheat flour control sampleswas 74.66 and increased during storage BP (78.55), PP (79.94), and LDPE (78.09). Significant ($p<0.05$) changes in ΔE and whiteness index on stored wheat flour with different packaging materials with respect to storage period were observed. The BP packaging material shows the lowest whiteness index on the 90th day of storage then other packaging materials due to less transparency. Also, this might be because the smaller particles have small pores and high uniformity, which minimises light absorption and increases light reflection (27).Smaller particles have small pores and excellent homogeneity, reducing light absorption and increasing light reflection.

Moisture

The moisture content of wheat flour packed in three different packaging materials (BP, PP, and LDPE) during storage are shown in Figure 1. A significant difference was observed in moisture content during storage ($P \leq 0.05$). The initial moisture content of wheat flour was measured as 8.52 % (dry basis). The highest moisture content measured asBP (10.97), followed by LDPE (10.80), and PP (10.54) respectively on 90th day of storage. At all three packaging materials, the BP films had the highest moisture content may be due to less thickness and low barrier for moisture transfer. Packaging materials with low thickness and tensile strength are insufficient to protect food products against moisture and air passage (28). There is no statistical difference among the packaging materials and statistical difference observed between the storage periods ($p<0.05$).Food samples with low moisture content had longer storage durations than those with higher moisture content (29). Low moisture content (less than 12 %) is beneficial and allows for a longer shelf life (30).Moisture losses were found lower in food during cold storage than atmospheric condition. This might be due to high storage temperature, which resulted in the evaporation of moisture from the component (13).

pH

The pH of wheat flour packed with different packaging materials and stored at room temperature is shown in Figure 2. The initial pH of wheat flour was found to be 6.28. During storage, the pH of wheat flour varied between 6.29 to 7.03 percent. Wheat flour stored in LDPE had the highest pH of 7.03, and wheat flour packed in BP has the leastpH value (6.87), respectively. It was observed that significant differences ($P \leq 0.05$) in pH of the wheat flour with packaging materials and storage period.The pH value of the wheat grains stored at 25 °C and 45 °C were found to be 5.92, and 4.98, respectively(31). Dhillon et al., (2020) reported that the pH of whole wheat flour was observed to be 6.81.

Particle size analysis

The particle size is an essential characteristic of any granular mix that has to be reconstituted with water.The particle size distribution of flour samples is shown in Table 3. Particle size (d_{10}, d_{50} and d_{90}), and span for control and 90th day of stored wheat flour samples were analysed for its fine flow conditions. The d10, d50, and d90 of control sample of wheat flour were measured as 101.45, 190.15, and 7008.15. The highest particle size measured in BP packaging material followed by LDPE, and PP due to moisture permeability.Span values of the wheat flour at 90th day stored samples were found to be decreased than the control.Significance differences were recorded at 95% confidence level of wheat flours particle size. The particle size distribution of cereal flours has a significant impact on the qualitative characteristics of their products. It has been hypothesised that the particle size of wheat flour affects the protein composition, damaged starch (DS) content, stretchability, and foldability of tortillas, with small particle size flour producing poor textural tortillas (33). The gluten network structure becomes more continuous and uniform as the particle size of wheat flour decreases(27).

Table 1 Colour values (L*, a*, &b*) of wheat flour in different packaging materials during storage

Storage Days	L Value			a Value			b Value		
	BP	PP	LDPE	BP	PP	LDPE	BP	PP	LDPE
0	$77.94\pm0.43^{a,1}$	$78.07\pm0.06^{a,1}$	$77.99\pm0.24^{a,1}$	$1.98\pm0.07^{a,1}$	$2.03\pm0.06^{a,1}$	$2.00\pm0.04^{a,2}$	$12.52\pm0.17^{b,1}$	$12.62\pm0.15^{b,1,2}$	$12.31\pm0.05^{a,1}$
15	$79.73\pm0.28^{a,2}$	$79.54\pm0.22^{a,2}$	$79.99\pm0.01^{a,2}$	$2.03\pm0.01^{a,1}$	$1.98\pm0.05^{a,1}$	$1.93\pm0.11^{a,1}$	$12.91\pm0.03^{b,1,2}$	$12.38\pm0.10^{a,1}$	$12.27\pm0.10^{a,1}$
30	$80.82\pm0.07^{b,3}$	$80.22\pm0.18^{a,2,3}$	$79.96\pm0.01^{a,2}$	$2.05\pm0.02^{b,1}$	$2.05\pm0.05^{b,1}$	$1.96\pm0.01^{a,1}$	$15.24\pm0.11^{b,4}$	$12.82\pm0.08^{a,1,2}$	$12.64\pm0.08^{a,1,2}$
45	$82.18\pm0.40^{b,4}$	$80.75\pm0.25^{a,3}$	$80.29\pm0.29^{a,2,3}$	$2.11\pm0.03^{b,2}$	$2.11\pm0.03^{b,2}$	$2.00\pm0.02^{a,2}$	$12.57\pm0.01^{a,1}$	$12.59\pm0.12^{a,1}$	$12.65\pm0.12^{a,1,2}$
60	$83.83\pm0.14^{c,5}$	$82.32\pm0.43^{b,4}$	$80.65\pm0.16^{a,3}$	$2.13\pm0.03^{b,2}$	$2.13\pm0.05^{b,2}$	$2.04\pm0.01^{a,2}$	$13.93\pm0.31^{b,3}$	$14.28\pm0.55^{b,3}$	$12.66\pm0.55^{a,1,2}$

75	83.89±0.74^{a,5}	83.69±0.73^{a,5}	83.47±0.09^{a,4}	2.15±0.04^{a,2}	2.14±0.04^{a,2}	2.13±0.01^{a,3}	15.68±0.54^{b,4}	15.07±0.14^{a,b,4}	14.53±0.14^{a,3}
90	84.50±0.13^{a,6}	87.20±0.02^{c,5}	85.12±0.13^{b,6}	2.21±0.04^{a,3}	2.62±0.04^{b,3}	2.24±0.04^{a,4}	16.00±0.12^{a,5}	16.11±0.68^{a,5}	15.55±0.12^{a,4}

All the values in the above table are represented Mean ± standard deviation form.
*Colour values ofBP (Bioplastics), PP (Polypropylene), and LDPE (Low density polyethylene) packaging materials, respectively. Different letters indicates significant differences among the packaging materials and numbers represent the significant differences among the storage period (p<0.05).

Table 2 Colour difference (ΔE) and whiteness index of wheat flour packed in different packaging materials during storage

Storage Days	ΔE			Whiteness index		
	BP	PP	LDPE	BP	PP	LDPE
0	1.05±0.34	1.78±0.54	1.02±0.65	74.66±0.39^{a,1}	74.66±0.39^{a,1}	74.66±0.39^{a,1}
15	1.90±0.63^{a,1}	2.05±0.43^{a,1}	1.60±0.47^{a,1}	76.00±0.23^{b,2,3}	76.45±0.01^{b,2}	75.89±0.25^{a,2}
30	4.12±0.25^{b,2}	2.34±0.53^{a,1}	2.05±0.42^{a,1}	75.42±0.12^{a,1,2}	76.34±0.20^{b,2}	76.23±0.01^{b,2,3}
45	4.24±0.53^{b,2}	2.82±0.40^{a,1}	2.37±0.31^{a,1}	76.90±0.27^{a,3,4}	77.16±0.05^{a,3}	76.49±0.29^{a,3}
60	6.12±0.29^{b,3}	4.80±0.86^{b,2}	2.73±0.55^{a,1}	77.69±0.45^{a,5}	77.53±0.58^{a,3,4}	76.79±0.15^{a,3,4}
75	6.85±0.60^{a,3,4}	6.39±0.60^{a,2,3}	5.96±0.33^{a,2}	77.89±0.10^{a,5}	78.12±0.36^{b,4}	77.40±0.22^{a,4}
90	7.60±0.50^{a,4}	9.82±0.37^{a,3}	8.10±0.42^{a,3}	78.55±0.24^{b,6}	79.94±0.13^{b,5}	78.09±0.33^{b,5}

All the values in table are represented **Mean ± standard deviation** form.
*ΔE and whiteness index of BP (Bioplastics), PP (Polypropylene), and LDPE (Low density polyethylene) packaging materials. Different letters and numbers indicates significant differences among the packaging materials and storage periods (p<0.05).

Table 3 Particle size distribution of control and stored wheat flour

Parameters	Control sample	Packaging materials		
		BP	PP	LDPE
Span value	37.17±1.23^{d}	5.13±0.01^{b}	5.03±0.18^{a}	5.32±0.07^{c}
d10	101.45±2.05^{a}	451.10±17.39^{c}	163.75±21.85^{a}	326.50±15.98^{b}
d50	190.15±11.95^{a}	2520.60±11.17^{d}	1428.45±65.27^{b}	1767.25±24.25^{c}
d90	7008.15±8.27^{a}	13426.45±69.23^{c}	7346.45±44.76^{a}	9738.25±17.89^{b}

Data are expressed as the mean ± standard deviation. Values in the same column with different letters are significantly different at p < 0 .05.
*BP (Bioplastics), PP (Polypropylene), and LDPE (Low density polyethylene) packaging materials.

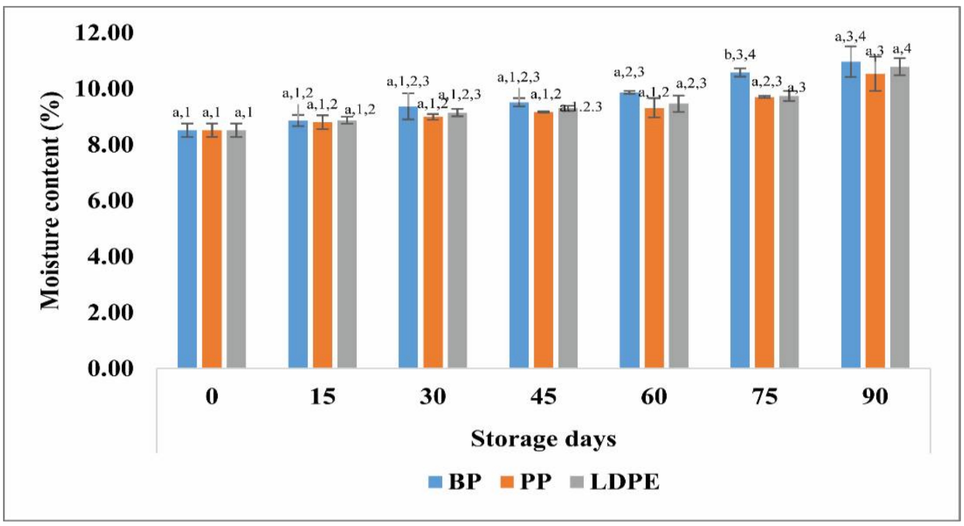

Figure 1. Moisture content of wheat flour packed in different packaging materials during storage.

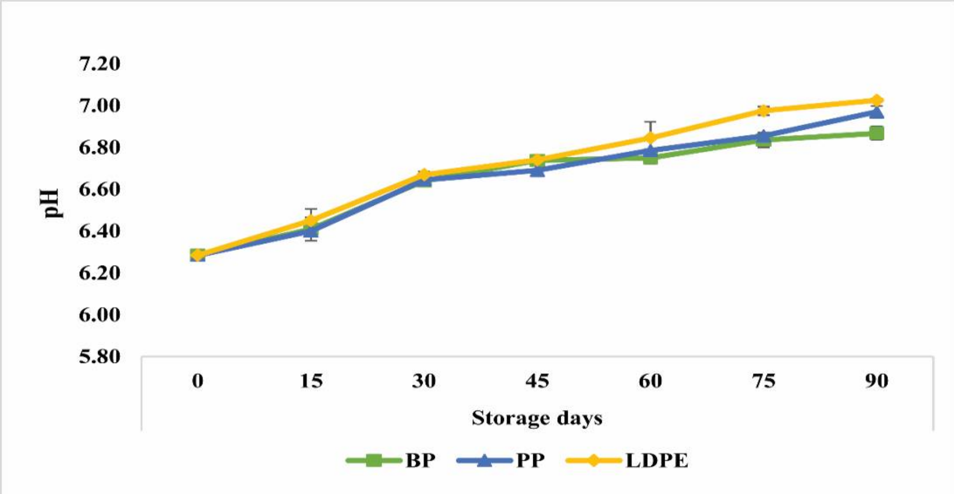

Figure 2. Effect of packaging materials and storage periods on pH of wheat flour during 90 days of storage.

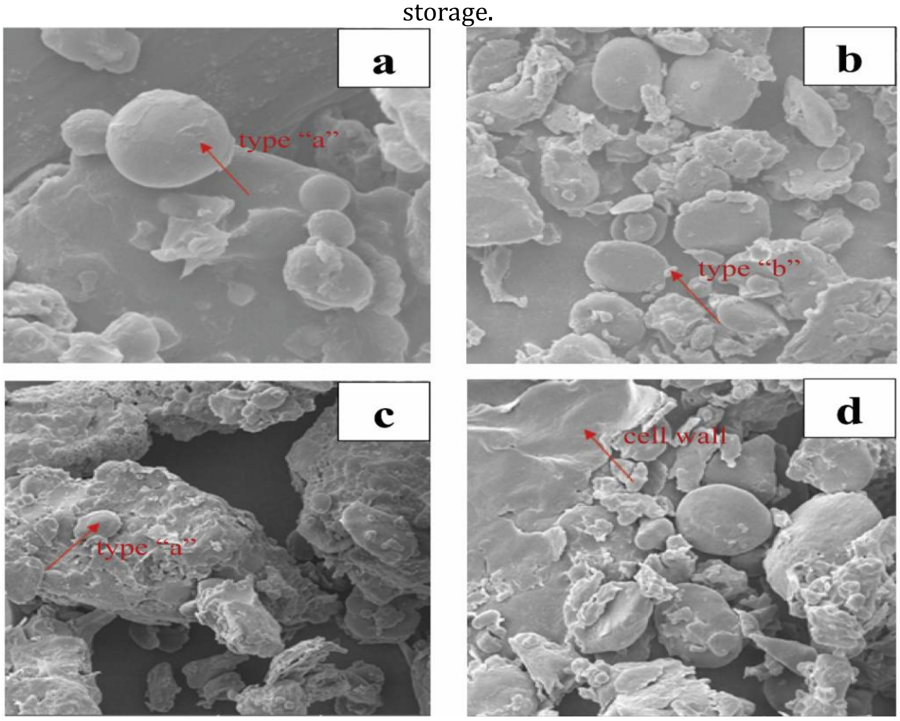

Figure 3. Scanning Electron Microscopic (SEM) images of wheat flour samples packed in different packaging materials; (a) control, (b) BP, (c) PP, and (d) LDPE.

SEM analysis

The scanning electron microscopy of the cross sections of the wheat flour samples can be seen in Figure 3. These micrographs depict the morphological features of wheat flour starch granules.From the figure, it is observed that smooth structure and uniform distribution of the particles in the morphologic appearancein control wheat flour. While, stored wheat flour containing many damaged starch particles and rough apparent was observed. The SEM images of stored wheat flour contains lenticular starch granules and particles of protein matrix and fiber.The type A-granules (larger granules)are smooth in appearance and had a lenticular, or disk-like form and type B-granules (small granules) were found to have a polygonal or spherical shapes [34]. The obtained results were found similar with the findings of [35], who observed a large number of tiny starch granules of type "b" with a smooth, clean surface and free from protein matrix. Wheat flour containing tiny agglomerates of big (type "a") and small starch granules, as well as protein matrix remains.

CONCLUSION
Three different types of packaging films, such as BP, PP, and LDPE were selected to evaluate the storage stability of wheat flour during storage at atmospheric condition for 90 days.During storage the moisture content and pH of wheat flour were increased in all the packaging materials. Among the treatments research significant differences (p <0.05) were observed. Particle size might be utilised to predict the product quality attributes or identify precise of flour quality. The findings showed that particle size was a significant determinant of wheat flour quality characteristics. The morphological appearances of stored wheat flour samples were explicated by scanning electron microscopy. The SEM indicated that the stored wheat flour sample contains more damaged starch particles when compared to control. This might be due to storage period and insect incursion mainly affected the stored wheat flour samples. The bioplastic packaging material has maintained the quality stability of wheat flour up to 60 days and PP and LDPE packaging materials were maintained the quality of wheat flour upto 75 and 90 days respectively.

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CONFLICT OF INTEREST
The authors declare that they have no conflict of interest.

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