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Effect of Packaging Materials and Storage Temperature on Garlic (Cv. Hg-17) Powder During Storage

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ABSTRACT

This study evaluates the impact of packaging materials on the shelf life of lye-peeled garlic powder stored at a temperature of 10-40°C. Garlic powder quality parameters such as moisture content, allicin content, colour and sensory parameters were measured for up to 6 months period. Results revealed that increases in temperature from 10 to 40ºC significantly accelerated the degradation of measured quality attributes, especially in low-density polyethene (LDPE) than aluminium foil pouch (AFP). In contrast, AFP-packaged products stored at low temperatures showed less moisture content and higher allicin content. The rate of degradation in colour was found to be lower in AFP as compared to LDPE in storage temperature of 10-40ºC up to 6-month period. The finding highlights the selection of appropriate packaging and storage conditions at a commercial scale to maintain the quality of garlic powder attributes.

Keywords: *AFP, Allicin, Colour, Garlic powder, LDPE, Shelf life.*

INTRODUCTION

Garlic is one of the bulbous crops used on a domestic scale in various food preparations and commercial as neutraceutical and pharmaceutical industries. Several studies show that it is a rich source of organosulfur (S-allyl-cysteine sulfoxide, diallylthiosulfinate, S-allyl-L-cysteine, allyl sulphide, and allyl mercaptan), and phenolic (quercetin, pyrogallol, hesperidin, catechin, protocatechuic acid) compounds play a vital role in various therapeutic namely antimicrobial, anticancer, immunity-booster, antioxidant, antidiabetic, and antiplatelet aggregation activity [1–3].

Mature cultivated garlic variety Haryana garlic-17 (HG-17) bulbs content approximately 65% moisture content [4]. The higher moisture content makes garlic susceptible to germination and microbial spoilage (about 30%) during conventional storage [5]. These make garlic qualitative and quantitative losses, therefore significant financial losses occurred to the sellers [6]. These losses may be decreased by drying for the production of garlic powder. Various studies revealed that drying can reduce about 90% of available moisture from food crops resulting in minimised transportation costs, and postharvest losses [7].

The shelf life of food powder is mainly influenced by the storage conditions such as temperature, humidity and packaging materials. Increases in moisture content may significantly affect the physicochemical, colour, sensory and powder flow properties. In parallel to that, these conditions may be favourable for fungal and mould growth [8].

The moisture content and water activity play a major role in the quality of food powder during storage [9]. Beyond these components, other factors such as packaging materials and packaging material environment play a significant role in extending the shelf life of the stored food powder [10]. As a result, food powder is highly susceptible to quality changes during storage. Experimentally determining its shelf life under every possible storage condition is complicated.

However, there is no variety-specific literature available on the shelf life of garlic powder. Different storage conditions can hasten the physicochemical, colour, and sensory properties changes in the product. Shelf life analysis helps anticipate these changes before experimental testing. When properly conducted, shelf life studies ensure that product quality is maintained throughout its lifecycle, significantly reducing the risk of customer complaints related to quality. Therefore, the present study was undertaken to evaluate the shelf life of garlic powder under different packaging and storage conditions, to improve its storage and transportation at an industrial scale.

MATERIAL AND METHODS

Materials

Mature harvested garlic bulbs (*Cv. HG-17*) were procured from CCS-HAU, Hisar, Haryana, India. (n-2-hydroxyethyl) piperazine-n'-(2-ethanesulphonic acid) (HEPS) buffer, 5,5'-dithio-bis-(2-nitrobenzoic acid) (DTNB), and L-cysteine were purchased from Central Drug House Pvt. Ltd. (India). All other chemicals were used of analytical grade.

Methods

Sample preparation

The HG-17 cloves were detached, lye-peeled (12% caustic solution at 40±2°C for 7 min), washed with tap water, pre-treated with 0.4% citric acid solution, and dried at room temperature to remove the surface water.

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The peeled cloves were cut into 3-4 mm thicknesses and dried at 55±1°C in a hot air oven up to constant weight. The dried garlic slices were stored in airtight containers. Before analysis, the dried garlic slices were converted into powder using an electric grinder and sieved through a 100-mesh sieve with a 149-micron opening.

Moisture content

The moisture content of garlic powder samples was determined by the standard method [11].

Allicin content

The allicin content was estimated by the method adopted [12].

Colour properties

The colour properties of garlic power were measured using a colourimeter (CR-10 model, Konica Minolta Sensing, Inc., Japan) attached with D 65 illumination. The colour values were represented in terms of 'L*'(ranging from 0 to 100, i.e., blackness to whiteness), 'a*' (ranging from -a to +a, i.e., greenness to redness), and 'b*'(ranging from -b to +b, i.e., blueness to yellowness). These measured values were further used to calculate the colour difference (ΔE) of the garlic powder, where an untreated garlic powder dried at the same temperature was taken as a control for comparison in the present study. The colour difference (ΔE) can be estimated using the equation 1.

$$\Delta E = \sqrt{[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]} \quad (1)$$

Where ΔL, Δa and Δb represent the difference in the 'L' value, 'a' value, and 'b' value of the garlic powder and the control garlic powder sample.

Sensory properties

The changes in sensory evaluation of dried garlic powder during the storage were evaluated by 35 semi-trained panellists as per the standard protocol (Ranganna, 2010). The samples were evaluated based on appearance, colour & aroma, and considered in terms of overall acceptability. A 9-point hedonic scale was used to evaluate the sensory parameters, where 1 represents the 'Dislike extremely' and 9 represents the 'like extremely'. The panellists evaluated the dried garlic powder during storage on their external senses, such as their nose, eye, and touch.

Statistical Analysis

The results were analyzed at least in triplicate and represented as mean±standard deviation (SD) of the arithmetic mean.

RESULT AND DISCUSSION

Storage of garlic powder

The influence of the different times and temperatures on the effect of moisture content, allicin content, colour parameters and sensory properties at different packaging materials were studied for the dried garlic powder and shown in Figures 1 (A) and (B), Figures 2(A) and (B), Table 1, and Figures 3(A) and (B), respectively.

Effect on moisture content

The moisture content variation of the dried garlic powder is shown in Figures 1(A) and (B). The initial moisture content of the garlic powder sample was 4.93±0.08%, and then it was increased to 5.22±0.05%, 5.26±0.07%, 5.62±0.08% and 5.81±0.07% at 10°C to 40°C, respectively for the LDPE packaging condition.

The moisture content significantly increased with the increase in the storage period from the initial to 180 days. The highest 5.81±0.07% moisture content was observed at the 180-day storage period stored at 40°C and lowest 4.93±0.08% in the initial stage. A significant difference in the moisture content was observed at 40°C compared to the other storage temperatures of 30, 20 and 10°C.

The same pattern was observed for the aluminium foil pouch (AFP) packaging, but there was less increase compared to the LDPE at different temperatures and storage conditions. The initial moisture content of the garlic powder (initial stage) was 4.93±0.08%, and then it was increased to 5.06±0.04%, 5.13±0.04%, 5.29±0.06%, and 5.32±0.06% from 10°C to 40°C respectively for the AFP packaging condition. The moisture content significantly increased with the increase in the storage period from the initial to 180 days. The highest 5.32±0.06% moisture content was observed at the 180-day storage period stored at 40° C, and the lowest 4.93±0.08% moisture content was observed at the initial stage. A significant difference in the moisture content was observed at 40° C when compared to the other storage temperatures of 30°C, 20° C and 10°C. The insignificant difference in the moisture content was observed at 10° C and 20°C and an increase of the moisture content from 4.93% control to 5.06±0.04% and 5.13±0.04%, respectively, for 180 days' storage period in AFP.

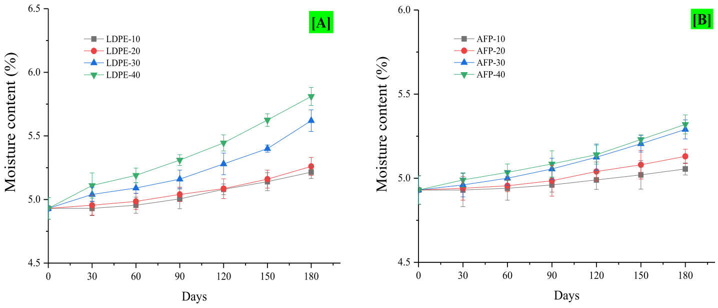

Figure 1. Effect of storage time and temperature on the moisture content of dried garlic powder (OGP) stored in [A] LDPE and [B] ALP

The results revealed that the maximum increase of moisture content was found at 40°C followed by the minimum at refrigerated temperature (10°C) and directly related to the storage period from 0 days to 180 days. More differences in moisture content were observed at 180 days at all temperatures compared to the other storage periods. There was less of an increase in the moisture content of dried garlic powder packed in AFP than in the LDPE packages stored in four temperatures. The water vapour permeability of ALP and LDPE were 6.14×10^{-12} and 3.38×10^{-11} kg water m^{-2} s^{-1} Pa^{-1}, respectively, as discussed [13,14]**.** The progressive increase in moisture content was noted in all the samples, possibly due to the powder's hygroscopic nature and differences in moisture content with different packaging materials due to the material's permeability to water. These results align with garlic powder stored in a brown glass bottle under ambient conditions [15]. Generally, 40°C temperature has been considered the most unfavourable condition for storage in domestic conditions, whereas industrial storage conditions vary in a wider range of temperatures and RH combinations (5, 10, 15, and 20 °C with 70% RH) [16,17].

The study revealed significant differences in moisture content between garlic powder samples packaged in LDPE and AFP across the temperature range of 10°C to 40°C and storage periods of 0 to 180 days. Both packaging materials effectively preserved moisture content at lower temperatures (10°C to 20°C), with minimal increase observed over the storage period.

However, at higher temperatures (30°C to 40°C) and longer storage durations (beyond 90 days), moisture absorption was more pronounced in garlic powder packaged in LDPE compared to AFP. The results highlight the interactive effects of packaging material, temperature, and storage duration on moisture content in garlic powder. AFPs provide superior moisture barrier properties compared to LDPE, particularly at higher temperatures and longer storage periods. Lower temperatures mitigate moisture absorption, emphasizing the importance of proper storage conditions for maintaining garlic powder quality. These findings have practical implications for food packaging and storage practices to minimize moisture-related deterioration in garlic powder products.

Effect on allicin Content

Figures 2(A) and (B) show the variation in the dried garlic powder's allicin content at different storage temperatures and storage periods. The study revealed significant differences in allicin content between dried garlic powder samples packaged in LDPE and aluminium foil pouches (AFP) across the temperature range of 10°C to 40°C and storage periods of 0 to 180 days. The initial allicin content of the dried garlic powder was 904.44±18.68 mg/100g on a dry basis (db). At lower temperatures (10°C and 20°C), both packaging materials effectively preserved allicin content, with minimal degradation observed over the storage period and maximum degradation was observed at 836.15±8.88 mg/100g and 860.55±10.20 mg/100g, respectively for LDPE and AFP of the dried garlic powder. The allicin degradation was more pronounced in garlic packaged in LDPE compared to AFP. Lower temperatures mitigate allicin degradation, emphasizing the importance of proper storage conditions for maintaining garlic quality. This also correlates with the lower moisture migration with the higher temperature over the prolonged storage time. However, at higher temperatures from 30°C to 40°C and longer storage durations beyond 90 days, allicin degradation was more pronounced in garlic packaged in LDPE compared to AFP. The maximum degradation in allicin content was observed at 40°C for both the packaging conditions and decreased from 904.44±18.68 mg/100g to 755.28±21.86 mg/100g for LDPE and 805.18±14.77 mg/100g for AFP. A similar pattern was also observed at 30°C but slightly less than 40°C over the increase in the storage period. The results highlight the interactive effects of packaging material, temperature, and storage duration on allicin stability in garlic. AFPs provide superior protection against temperature-induced degradation compared to LDPE, particularly during prolonged storage. Lower temperatures mitigate allicin degradation, emphasizing the importance of proper storage conditions for maintaining garlic quality. These findings have practical implications for food packaging and storage practices to optimize allicin preservation in garlic-based products. A similar pattern was also observed [18]. They suggested that the LDPE/AL/LDPE pouch and storage temperature of 30°C provided promising packaging materials and storage conditions to preserve the quality and stability of bioactive compounds in dried garlic

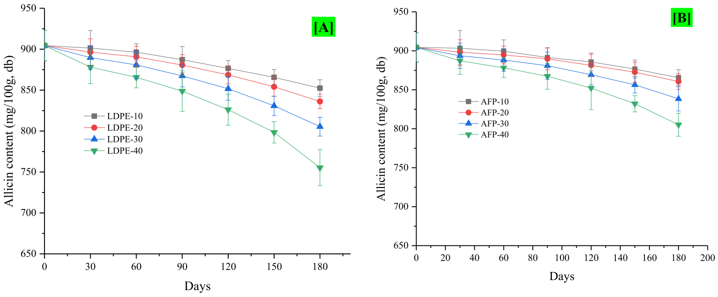

Figure 2. Effect of storage time and temperature on allicin content of dried garlic powder (OGP) stored in [A] LDPE and [B] ALP

The study found that allicin content varied significantly depending on the packaging material, temperature, and storage duration. AFP exhibited better allicin retention than LDPE Packaging, particularly at higher temperatures. Allicin degradation was more pronounced at elevated 30 and 40°C temperatures and prolonged storage durations beyond 90 to 180 days. However, even under optimal packaging conditions, a gradual decline in allicin content was observed over time. AFP packaging, having its superior barrier properties of water vapour transmission ratio (WVTR) offers better protection against external factors such as light, moisture, and oxygen than the LDPE, thereby reducing allicin degradation. The postharvest physiology and texture of garlic cloves packaged in polyethene terephthalate (PET), polyethene (PE), aluminized kraft paper (AKP), single kraft paper (SKP), and mesh bag and as per the findings PE effectively reduced the degree of damage to the cell membranes of the garlic cloves (19). PE and SKP significantly inhibited respiratory intensity during storage. The water content of garlic cloves did not change significantly in 90 days of storage when packaged in PE and SKP. PE exhibited a better effect on the texture and freshness of garlic cloves than the other materials. Temperature also significantly influences allicin stability, with higher temperatures accelerating the rate of degradation. Therefore, storing garlic at lower temperatures is recommended to prolong its shelf life and retain allicin content. Additionally, minimizing storage duration can help mitigate allicin loss over time [18].

Effect on colour properties

The change in colour of the dried garlic powder is shown in Table 1. The garlic powder showed maximum L* values change (initial stage) from 88.50±2.12 to 70.50±3.54 for LDPE and 78.00±2.83 for AFP at 180 days' storage period were observed at 40ºC. A major reduction in the L* lightness value was observed at 30 and 40°C when compared to the lower storage temperature. The result also suggests that the more reduction in the L* value of the dried garlic powder in LDPE compared to the AFP over the increase in the storage temperature and the storage period. This may be due to the transparent nature of the LDPE packing material, which might expose the garlic powder to light and lead to colour changes due to photochemical reactions. Oxygen exposure can cause oxidation, which may alter the colour of the garlic powder, and higher temperatures also accelerate oxidation reactions, leading to colour changes.

The results revealed that the maximum increase of change in colour was found in the 40°C temperature storage, and lower changes were found at refrigerated storage (10°C). There was less of an increase in the colour of garlic powder packed in ALP than in the LDPE packages stored in four temperatures. The same results were also reported for dried garlic powder packaged in high-density polyethene (HDPE), low-density polyethene (LDPE), and aluminium laminated pouch (ALP) under accelerated storage temperature (5 to 40°C) and humidity (70–90% RH) conditions [5].

The maximum a* values of the dried garlic powder were increased from 1.50±0.71 to 16.50±2.12 for LDPE and 10.50±0.71 for AFP at 40ºC for 180days storage period. The major reduction of a* value was observed at 30 and 40°C when compared to the lower temperature storage temperature. The result also suggests a reduction in the * value of the dried garlic powder in LDPE compared to the AFP over the increase in storage temperature and storage period. This may be due to the transparent nature of the LDPE packing material, which might expose the garlic powder to light, leading to colour changes due to photochemical reactions and the Millard reaction. Oxygen exposure can cause oxidation, which may alter the colour of the garlic powder, and higher temperatures also accelerate oxidation reactions, leading to colour changes.

A similar pattern was also observed for the b* value, representing the garlic powder's blue to yellow from 12.50±0.71 to 24.00±2.83 for LDPE and 21.00± 1.41 for AFP at 40ºC for 180 days' storage period. The major reduction of the b* greenness to redness value was observed at 40°C and further at 30°C when compared to the lower storage temperature. The result also suggests a greater reduction in the b* value of the dried garlic powder in LDPE compared to the AFP over the storage temperature and storage period. This may be due to the higher WVTR and OTR of the LDPE packing material, which might expose the garlic powder to light, leading to colour changes due to photochemical reactions, Millard reaction and enzymatic browning. Oxygen exposure can cause oxidation, which may alter the colour of the garlic powder, and higher temperatures also accelerate oxidation reactions, leading to colour changes.

A similar pattern was reported for changes in ΔE value in colour, combining all the three colour parameters of L*, a* and b* colour value. The maximum colour change was observed at 40°C and further at 30°C, 20ºC and lower storage temperature(10ºC). The results confirm the findings reported by [20–22].

Table 1. Effect on colour properties of dried garlic powder (OGP) stored in [A] LDPE and [B] ALP.

Storage period (days)	L*		a*		b*		ΔE	
	LDPE	AFP	LDPE	AFP	LDPE	AFP	LDPE	AFP
0 (control)	88.50±2.12		1.50±0.71		12.50±0.71			
Storage temperature (10°C)								
30	87.50±0.71	88.50±0.71	1.50±0.71	2.00±0.00	13.50±0.71	12.50±0.71	2.52±1.12	1.57±0.22
60	85.00±2.83	86.50±6.36	2.50±0.71	2.50±0.71	14.00±2.83	13.50±2.12	4.79±0.30	4.32±1.64
90	84.50±2.12	86.00±4.24	3.50±0.71	3.00±0.00	15.00±1.41	15.00±1.41	5.29±1.00	4.41±0.24
120	84.00±4.24	85.00±4.24	4.50±0.71	3.50±0.71	16.50±0.71	15.50±0.71	6.82±2.02	5.37±1.12
150	81.50±3.54	82.50±2.12	6.50±0.71	4.50±0.71	17.50±0.71	16.50±0.71	9.98±0.99	7.81±0.00
180	79.00±2.83	81.50±2.12	8.00±1.41	6.50±0.71	18.50±2.12	16.50±0.71	13.03±0.81	9.49±0.00
Storage temperature (20°C)								
30	87.50±0.71	87.00±1.41	1.50±0.71	2.00±0.00	14.50±0.71	13.50±0.71	3.10±0.91	2.12±1.00
60	84.50±4.95	87.00±1.41	3.50±0.71	2.00±0.00	15.00±2.83	14.00±1.41	6.03±0.41	2.51±1.55
90	83.50±3.54	84.50±3.54	4.50±0.71	3.50±0.71	16.00±2.83	15.50±2.12	6.84±2.74	5.82±0.49
120	81.50±2.12	83.50±2.12	5.50±0.71	6.00±1.41	17.00±1.41	17.00±1.41	9.24±0.34	8.17±1.56
150	80.00±2.83	82.00±2.83	7.00±1.41	7.00±0.00	18.00±1.41	17.50±0.71	11.57±1.86	9.95±0.14
180	77.50±3.54	79.00±1.41	10.00±1.41	7.50±0.71	19.50±2.12	19.00±1.41	15.90±3.67	13.03±0.49
Storage temperature (30°C)								
30	86.00±1.41	85.50±0.71	3.00±1.41	2.50±0.71	14.50±0.71	14.00±1.41	3.86±0.37	3.91±1.54
60	85.00±4.24	85.50±2.12	5.50±0.71	4.50±0.71	17.00±1.41	15.50±2.12	7.34±0.48	5.63±0.75
90	82.50±3.54	83.50±2.12	7.00±1.41	6.00±1.41	17.50±0.71	16.00±1.41	9.67±0.26	7.68±1.38
120	79.00±1.41	82.50±3.54	8.00±1.41	7.00±1.41	19.00±1.41	17.00±1.41	13.52±1.12	9.36±0.83
150	77.50±0.71	81.00±1.41	11.00±1.41	8.50±0.71	20.00±2.83	17.00±1.41	16.46±0.39	11.26±0.69
180	74.50±3.54	78.50±2.12	13.50±2.12	10.00±1.41	22.50±2.12	19.50±2.12	21.10±1.21	15.11±2.55
Storage temperature (40°C)								
30	83.00±1.41	85.00±1.41	3.50±0.71	2.50±0.71	14.50±0.71	14.50±0.71	6.19±0.63	4.21±1.26
60	83.50±3.54	84.50±2.12	7.00±1.41	5.50±0.71	17.00±1.41	16.00±1.41	8.87±0.72	6.67±0.37
90	82.50±3.54	83.00±1.41	9.00±1.41	6.50±0.71	18.50±2.12	17.00±2.83	11.52±1.20	9.22±0.31
120	77.50±3.54	81.50±2.12	11.50±2.12	8.00±1.41	20.50±2.12	18.50±0.71	17.04±1.25	11.29±0.41
150	72.50±3.54	79.50±2.12	13.50±2.12	9.00±1.41	22.50±3.54	20.00±1.41	22.79±4.34	14.07±0.00
180	70.50±3.54	78.00±2.83	16.50±2.12	10.50±0.71	24.00±2.83	21.00±1.41	26.31±1.03	16.34±0.13

Results are mentioned as mean±S.D (n=3)

Effect on sensory properties

Sensory properties of dried garlic power at different temperatures, storage times, and packaging conditions were presented in Figures 3(A) and (B). The overall acceptability (OAA) was found to be 8.19±0.26 at 10ºC, 8.13±0.35 at 20ºC, 7.97±0.34 at 30ºC, and 7.69±0.26 at 40ºC in AFP, whereas it was found to be lower in LDPE, i.e. 8.09±0.13 at 10ºC, 7.97±0.28 at 20ºC, 7.56±0.42 at 30ºC, and 7.44±0.32 at 40ºC. It was clearly evidence from Figure 3 that with an increase in temperature, the OAA score decreases in LDPE as well as in AFP, but the score value was higher in the case of AFP as compared with ADPE. However, the OAA was found to be above 7.0 in all the storage conditions, which means that all the garlic powder samples were above the moderate range. Similar observations were reported for the dried garlic flakes stored in LDPE, aluminium pouch, and HDPE [23]. The decrease in sensory scores can also be attributed to the decrease in colour parameters and flavour of the garlic powder in LDPE and AFP at different temperatures (10 to 40ºC) during the storage period, compared to fresh garlic powder. The results also confirmed the findings mentioned [21,24].

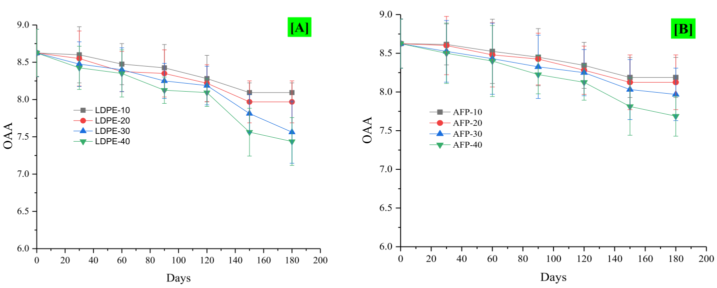

Figure 3. Effect of storage time and temperature on overall acceptability (OAA) of dried garlic powder (OGP) stored in [A] LDPE and [B] ALP

CONCLUSION

Storage temperature and packaging materials affect the storage period of garlic powder. Moisture content increased in both the storage condition (packaging material and environment temperature) during the storage period. It was found to be higher in LDPE and storage temperature. Allicin content decreased in both storage conditions during the storage period but decreased faster in LDPE storage conditions and with increased temperature. Aluminium foil pouches (AFP) and lower temperatures were found to be more suitable for packaging and storage of garlic powder than low-density polyethene (LDPE) based on colour and sensory parameters.

FUTURE SCOPE OF STUDY: This research may be carried out with active and biodegradable eco-friendly packaging material at different storage conditions.

CONLICT OF INTEREST: The authors declare no conflict of interest.

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