Effect of grinding methods and packaging materials on fenugreek and black pepper powder quality and quantity under normal storage conditions

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Abstract: The effects of different grinding methods and packaging materials on qualities of fenugreek and black pepper powders were evaluated. Various parameters and their evaluation methods are as follows: change in colour determined using Chroma meter calorimeter, aroma and odour measured by sensory evaluation, and change in moisture measured using oven drying method. Packaging materials such as glass jar, steel jar, plastic jar, aluminum bag and poly bags were used for keeping ambient and cryogenically ground fenugreek and black pepper powders. Packed powders were stored in dry and cool places under ambient condition. Sensory evaluation revealed quality reduction in terms of colour, odour, flavour, aroma and acceptability for fenugreek and black pepper powder stored for a long term (6 months). However, glass jar and steel jar were found to be better containers for storing powders for longer storage period than other options. For practical applications, the present investigation on the deterioration behaviour of fenugreek and black pepper powder contributes to the design of a suitable grinder out of ball, hammer, rotor, and pin mill for spice grinding. The study also helps select a suitable packaging material or container to store spice powders. A method to assess the quality of stored powder and its deterioration with the storage time is provided.

Keywords: grinding method, packaging material, storage condition,,quality deterioration, behavior, aroma, cryogenic, ambient
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1 Introduction

Quality of a food product in terms of colour, aroma, appearance, texture and flavour is time dependent and is important factor to grade food quality. Some of the food and its constituents lose quality and quantity because of processing such as grinding[1], heating, cooking, boiling[2,3] freezing, packing and transportation etc. On the other hand, storing food and its constituents over a period of time also loses quality[4]. Food or its materials losses its quality with the storage time and food materials get spoiled due to oxidation, because oxidation is a major cause of chemical spoilage of food. Oxidation of food leads to rancidity and deterioration of the nutritional quality of food. Colour, flavour, texture and safety of food are lost due to oxidation[5]. The best way to overcome oxidation problem of food is to use natural antioxidant such as use of spices having natural antioxidant activity. Black pepper and fenugreek have natural antioxidant activities and these can be helpful to prevent oxidation of food[6]. Any food material or its constituents kept over a period of time will lose its strength, quality, colour and nutritional value. Rate of losing quality varies based on the type of packaging material, surrounding conditions and storage conditions.

There are various packaging materials generally used in household for storing spices[7] and they have various

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categories. In primary type of packaging material, packing wrap is in direct contact with food material and are taken home by the consumers[7]. Packaging materials like papers, cloths, jute bags are flexible; they have light weight and recyclability. Metallic and glass packaging materials are strong and corrosion resistant but costly. Weight and careful handling are limiting factors for using metallic and glass packaging material in their usage.

Polymers are commonly used for packaging due to their transparency, softness, heat sealing capacity, low cost, good mechanical property and they also have good barrier to heat and oxygen[7,8]. One of the limiting natures of packaging materials, which controls the shelf life of packed products, is the migration of moisture or permeability of moisture through the packaging material evaluated by the sorption isotherm. This requires understanding of transfer mechanism of low molecular weight molecules through the packaging material that controls the exchange of the molecules such as aroma compounds, volatile compounds, water vapors etc.[9]. Even a minute quantity of aroma compounds of packaging material when penetrates into the food material, aroma compounds of packaging material will change the organoleptic quality of the food materials. Presence of odd aroma compounds may change the product quality and lead to rejection of the food products[10]. Based on the observations of common practical use, fenugreek and black pepper powders obtained from cryogenic and ambient grinding were packed in different containers such as glass jar, steel jar, plastic jar, aluminum bag and poly bag immediately after grinding.

Colour and appearance of any food product helps in judging the acceptability of the product. The sensory quality of the food or its item may affect the decision making process of purchasing food materials by the consumers[11].

The main aim of the present study was to investigate the change in quality of powder with the storage time in terms of colour value, flavour, aroma, mass change, moisture content (MC), biological change and change in antioxidant activity. The present study also aims to study the effect of different types of packaging materials on quality aspects of spice powders.

2 Material and methods

2.1 Sample preparation

Fenugreek and black pepper seeds were selected and collected from National Research Centre for Seed Spice–Ajmer, Rajasthan and Indian Institute of Spices Research Marikunnu, Calicut, Kerala, respectively. Cleaned fenugreek and black pepper seeds were ambient and cryogenically ground[12] and packaged.

2.2 Ambient grinding of fenugreek and black pepper seeds

Using Rotor mill, fenugreek and black pepper seeds were ground under ambient conditions of temperature and pressures. Then, the ground powder was packaged in selected packaging materials and marked them accordingly.

2.3 Cryogenic grinding of fenugreek and black pepper

Cryogenic grinding of fenugreek and black pepper samples were carried out using Rotor mill. Liquid nitrogen (LN_2) was used as cooling agent. Seed samples were first dipped into LN_2 to remove its sensible heat (pre-cooling) and then the same cooled samples were fed into the feed hopper of the grinder along with LN_2 at a suitable rate for cryogenic grinding. Ground powders were packed and duly marked.

2.4 Sample packing and quality analysis

Packed samples were stored in dry (relative humidity of 75% to 82%) and cool place (28 ± 1) ^{o}C. The samples of fenugreek and black pepper powders were packed in containers of different materials such as glass jar, plastic jar, steel jar, aluminum bags and poly begs. Various selected parameters were determined over a period of time with these samples. Fenugreek and black pepper Powders obtained from ambient and cryogenic grinding using Rotor mill were packed in various types of packaging materials. AG and CG stands for the ambient and cryogenic grinding respectively; Fenu and BP stands for fenugreek and black pepper samples, respectively.

2.5 Colour determination of fenugreek and black pepper powders

Appeal and fresh colour of the food product is the

most useful requirement and it creates first impression in the minds of consumers[13]. Natural colour of the product should be preserved and saved from deterioration and damage to keep high quality and demand of the product. Colour of the product has direct appealing effect in the mind of the consumer and it helps in accepting or rejecting the powder[14]. In this investigation, the change in the colour with the storage time was studied with the help of Chroma Meter (Konica Minolta, CR-400, Japan). 'L', 'a' and 'b' values were obtained from Chroma meter, where 'L' value varied between 0 and 100. A perfectly white body has 'L' value of 100 and that of a black body is 0. A positive value of 'a' indicates the redness and negative value indicates greenness. A positive value of 'b' indicates yellowness and negative value of 'b' shows blueness. In a standard colour chart, at the centre, values of 'a' and 'b' are zero and they show gray colour[15].

Whiteness index and yellowness index of fenugreek and black pepper powder were determined with the help of following relationships as shown in Equations (1), (2), (3) and (4):

$$Y = L^2/100 \quad (1)$$

$$Z = 1.18103L\ (L/100 - b/70) \quad (2)$$

$$WI = 3.388Z\text{-}3Y \quad (3)$$

$$YI = 142.86b/L \quad (4)$$

where, Y stands for yellowness; Z is a constant value assumed for whiteness index determination; WI stands for whiteness index; YI stands for yellowness index.

The sensory evaluation of fenugreek and black pepper powders were done for detecting any change in its colour values and its colour indices[16].

2.6 Sensory evaluations (SE)

Aroma and flavour of the powders were analyzed by sensory evaluation method.

2.6.1 SE-Aroma and flavour

Aroma and flavour of fenugreek and black pepper are very important factors which determine its economy, demands, acceptance or rejection[6]. Thirty five panelists have been selected and trained about the samples to be tested and its sensory evaluations[15]. Male and female of 25 to 35 years of age group were selected as panelists (35 panelists (i.e., 14 female and 21 male)) and were trained to judge the samples.

Powders of various samples were judged by these experts for colour, flavour, aroma and acceptability. The experts were instructed to record their rating using 5 point hedonic scale. The average quality attributes were designated as follows: 1 was "Not satisfactory", 2 was "Fair", 3 was "Medium", 4 was "Good", 5 was "Very good"[15]. Colour was determined under ordinary condition of room light. The average values were reported along with standard deviation.

2.6.2 SE - Change in appearance

Appearance is the direct appealing effect in the consumer's memory and it cannot be measured but it can be evaluated by sensory evaluation method[11,15]. The change in appearance in fenugreek and black pepper powder were evaluated by sensory evaluation method with the help of 35 trained experts (i.e., 14 females and 21 males) and the results are reported in results and discussion section.

2.6.3 SE - Overall acceptability

Overall acceptability is a comparative judgment of samples based on their colour, appearance, aroma and related other factors[11]. Fenugreek and black pepper powders were analyzed for their overall acceptability with the help of 35 trained experts (i.e., 14 female and 21 male) by sensory evaluation method.

2.7 Change in moisture content

The moisture contents of the fenugreek and black pepper samples were analyzed to ascertain any change in its moisture content. Every month, about 3 g powder was taken and it was used for its moisture content determination using oven dry method[17,18]. The sample packed and arranged for quality deterioration study were stored at room temperature in dry and cool place. The moisture content was determined using hot air oven (Rinotek Hot Air Oven, Riviera Glass Pvt Ltd, Munbai, India) method.

2.8 Change in weight

Weight of a spice commodity also has direct relationship with its cost and it influences the profit. In the present investigation changes in weight of the set powder samples were observed every month by weighing them in electric weighing balance (DC 170, Ohaus Corp.,

Teraoka Seiko, Ltd. USA).

2.9 Antioxidant activities of powder

Antioxidant is the molecule that inhibits the oxidation of other active molecules. Oxidation molecules lead to much health related problems in human body. In the modern age, food and nutrition companies are looking for the availability of antioxidants in their products because among the health conscious consumers a interest has greatly been developed in the potential health benefits of antioxidants in the diet. Antioxidant activities of spices act as health protecting factors and antioxidants are used as additives in food processing to prevent food spoilage[6]. It has been found from the published literature on fenugreek and black pepper that they are good sources of antioxidant[19,20]. In the present study, fenugreek and black powder were evaluated for their antioxidant activities retained with the storage time. 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical method, total phenolic content (TPC) and the ferric reducing ability of plasma (FRAP) assay were used to determine the antioxidant activity of these selected powders. Odd electron present in DPPH, free radical provide high absorption, maximum at 517 nm and it was of purple in colour. The colour changed from purple to yellow because the molar absorptivity of the DPPH radical at 517 nm decreased from 9660 to 1640 while the odd electron of DPPH radical got paired with a hydrogen from a free radical scavenging antioxidant to form the reduced DPPH-H[21]. Based on the number of electrons captured, obtained de-colourizations was stochiometrically ascertained[22].

2.10 Biological deterioration of fenugreek and black pepper powders

Fenugreek and black pepper samples were packed in plastic jars and stored in dry and cool place for more than 2½ years to observe attack and spoilage due to insects.

3 Results and discussion

3.1 Deterioration of fenugreek and black pepper powder

The quality of the fenugreek and black pepper powder were found to be diminishing with the storage time. The present investigation tried to quantify and assess the decrease in the quality of the powder in terms of colour, colour indices, volatile contents, aroma, mass loss and change in the moisture content of the fenugreek and black pepper powder stored under ambient conditions.

3.2 Changes in colour of fenugreek and black pepper

The colour of the powders was found to undergo significant change. The colour values were determined in terms of whiteness and yellowness index of fenugreek and black pepper powder[14]. Figure 1 and Figure 2 show the variation in whiteness and yellowness index of the powders over a period of six months' time. Figure 1 shows the increase in the whiteness index of the black pepper powder during its storage and it can be depicted from this graphical presentation that ground black pepper powder is losing its blackish freshness during storage and became comparatively dull in colour.

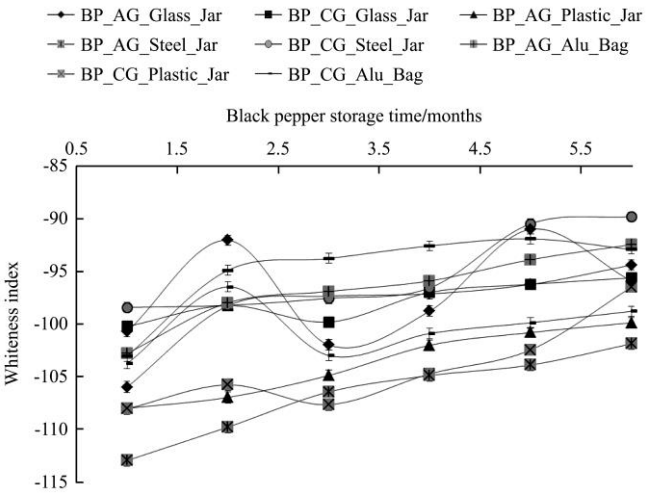

Figure 1 Whiteness index of ambient and cryogenically ground black pepper powder

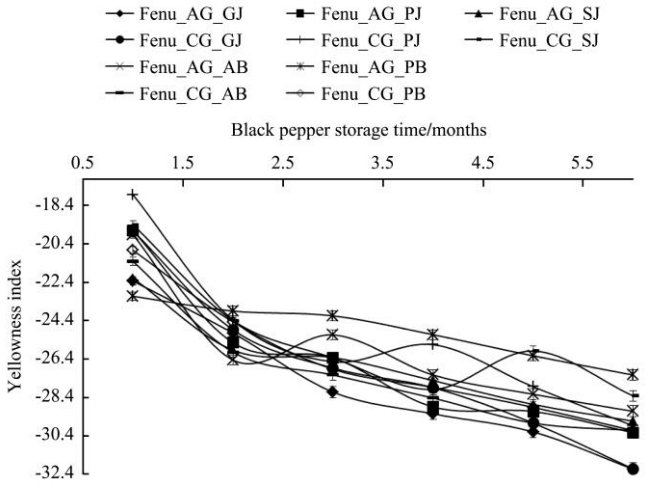

Figure 2 Yellowness index of ambient and cryogenically ground fenugreek powder

It is found from the colour values of ambient and

cryogenically ground black pepper powder packed and stored in various kinds of containers that ΔL, Δa, Δb and ΔC values are increasing in nature but *h* values have been found to be decreasing in trend (Δ shows the difference in color values). The ΔL, Δb and ΔC values of fenugreek powder obtained under ambient and cryogenic grinding conditions are found to be decreasing in nature whereas Δa values of the same are found to be increasing in nature (Table 1). The freshness of fenugreek powder was expressed in yellowness index and it was found to be decreasing which implied that the powder was losing its freshness in terms of yellow colour (Figure 2).

Table 1 Chroma meter colour values of stored powders under present study

	ΔL			Δa			Δb		
Time (Days)	15	90	180	15	90	180	15	90	180
BP_AG_Glass_Jar	37.95±0.03	41..21±0.03	46.46±0.01	3.85±0.01	3.85±0.02	3±0.01	11.68±0.01	12.00±0.02	13.42±0.03
BP_AG_Plastic_Jar	35.96±0.02	36.12±0.01	48.85±0.03	3.2±0.02	3.4±0.01	3.6±0.02	12.78±0.01	12.88±0.03	12.98±0.02
BP_AG_Steel_Jar	32.44±0.01	44.36±0.02	50.94±0.02	3.5±0.01	4.21±0.02	4.88±0.01	11.81±0.03	12.55±0.02	13.40±0.01
BP_AG_Alu_Bag	33.34±0.03	38.59±0.01	49.85±0.01	2.91±0.02	3.21±0.01	4.99±0.02	10.99±0.03	13.25±0.01	15.53±0.02
BP_AG_Poly_Bag	34.47±0.01	42.13±0.01	50.79±0.03	2.95±0.01	3.86±0.02	5.29±0.01	11.33±0.04	13.57±0.03	15.45±0.01
Fenu_AG_Glass_Jar	65.52±0.02	59.38±0.03	54.91±0.01	0.68±0.03	1.96±0.02	2.74±0.01	27.36±0.03	23.12±0.01	18.94±0.02
Fenu_AG_Plastic_Jar	59.78±0.02	58.25±0.01	57.47±0.01	-0.21±0.02	1.65±0.01	2.80±0.03	25.36±0.01	22.36±0.04	20.36±0.02
Fenu_AG_Steel_Jar	59.87±0.01	56.21±0.02	54.59±0.03	0.49±0.01	1.65±0.02	2.93±0.03	25.83±0.02	23.26±0.01	19.12±0.03
Fenu_AG_Alu_Bag	64.02±0.03	63.11±0.01	61.46±0.04	-0.03±0.02	1.21±0.01	1.96±0.02	26.31±0.03	25.26±0.01	26.24±0.02
Fenu_AG_Poly_Bag	62.99±0.01	62.01±0.03	61.38±0.01	0.59±0.02	1.87±0.03	2.27±0.02	27.83±0.01	23.63±0.03	21.84±0.01
BP_CG_Glass_Jar	35.14±0.02	36.21±0.01	37.12±0.02	3.02±0.03	3.32±0.01	3.45±0.02	11.22±0.01	11.39±0.03	11.57±0.02
BP_CG_Plastic_Jar	33.52±0.02	34.56±0.03	36.71±0.01	3.31±0.02	3.77±0.02	3.92±0.01	11.60±0.03	12.02±0.02	12.31±0.01
BP_CG_Steel_Jar	34.11±0.01	42.21±0.01	50.25±0.03	2.97±0.02	4.32±0.01	5.1±0.03	10.76±0.02	11.97±0.01	13.37±0.02
BP_CG_Alu_Bag	35.84±0.03	41.85±0.02	50.17±0.01	3.12±0.02	3.88±0.02	4.99±0.03	11.79±0.01	12.89±0.04	15.43±0.02
BP_CG_Poly_Bag	36.87±0.02	43.52±0.01	50.8±0.01	3.22±0.02	4.56±0.02	5.28±0.01	11.75±0.04	13.02±0.02	15.06±0.03
Fenu_CG_Glass_Jar	65.90±0.01	63.23±0.03	61.04±0.01	0.02±0.02	1.23±0.02	2.60±0.01	26.43±0.05	23.12±0.03	21.71±0.02
Fenu_CG_Plastic_Jar	67.54±0.02	63.81±0.01	59.59±0.02	-0.88±0.02	1.63±0.01	2.26±0.03	27.86±0.04	24.06±0.02	21.77±0.03
Fenu_CG_Steel_Jar	58.42±0.01	58.41±0.03	58.38±0.01	0.18±0.02	1.35±0.01	2.53±0.02	23.01±0.03	21.58±0.04	20.33±0.02
Fenu_CG_Alu_Bag	60.70±0.03	59.21±0.01	58.66±0.02	0.55±0.02	1.65±0.01	2.04±0.02	24.76±0.04	24.49±0.02	24.20±0.03
Fenu_CG_Poly_Bag	58.92±0.01	58.75±0.02	58.53±0.03	0.44±0.01	1.23±0.02	2.53±0.03	23.82±0.05	21.58±0.03	20.47±0.02

3.3 Sensory evaluations (SE)

Table 2 shows sensory attributes (i.e, color, aroma and overall acceptability) of ambient and cryogenically ground fenugreek and black pepper powders stored at 25-28^{o}C at 75%-85% RH, kept in different packaging materials under ambient storage condition. Color values of powders in all containers were found to be diminishing but it was more prominent for ambient ground powder kept in poly bags compared to those kept in glass and steel jars. Aroma was found to be losing due to the escape of flavor notes. Sensory analysis suggested that cryogenically ground powder stored in glass jar and steel jar had better color, aroma and overall acceptability compared to those of ambient ground powder stored in aluminum and poly bags (Table 2).

3.4 Changes in moisture content of fenugreek and black pepper samples

It was found that there were minute fluctuations in the moisture content of the samples. In cryogenically ground sample, a little rise in moisture content was observed while comparing with whole seed whereas no such observation was noticed in ambient ground samples (Table 3). It was observed that there was no observable fluctuation in the MC in powder samples packed in glass jar and steel jar because they were compact in design and inert in nature but significant fluctuations were noticed in case of aluminum and poly bag packed samples due to their poor closing facility of the mouth of the packet and its permeability.

Table 2 Sensory attributes of ambient and cryogenically ground fenugreek and black pepper powders stored at 25-28°C at 75%-85% RH

	Colour			Aroma/Flavour			Acceptability		
Time (Days)	0	90	180	0	90	180	0	90	180
BP_AG_Glass_Jar	4.77±0.07	4.76±0.04	4.75±0.06	4.80±0.06	4.78±0.08	4.76±0.03	4.79±0.09	4.78±0.06	4.76±0.05
BP_AG_Plastic_Jar	4.51±0.01	4.49±0.05	4.40±0.06	4.65±0.01	4.51±0.01	4.40±0.08	4.55±0.03	4.50±0.08	4.39±0.01
BP_AG_Steel_Jar	4.78±0.08	4.74±0.09	4.71±0.09	4.75±0.07	4.71±0.06	4.70±0.04	4.73±0.05	4.71±0.04	4.65±0.07
BP_AG_Alu_Bag	3.49±0.07	3.46±0.06	3.39±0.02	3.48±0.03	3.42±0.07	3.39±0.05	3.49±0.06	3.41±0.02	3.29±0.05
BP_AG_Poly_Bag	3.75±0.01	2.68±0.02	2.84±0.02	3.47±0.07	3.37±0.01	3.35±0.02	2.69±0.01	3.31±0.09	3.25±0.06
Fenu_AG_Glass_Jar	4.85±0.02	4.83±0.08	4.81±0.08	4.83±0.03	4.81±0.06	4.79±0.01	4.79±0.05	4.76±0.08	4.73±0.01
Fenu_AG_Plastic_Jar	4.81±0.03	4.76±0.05	4.72±0.07	4.79±0.01	4.77±0.03	4.51±0.01	3.99±0.06	3.89±0.01	3.85±0.03
Fenu_AG_Steel_Jar	4.88±0.05	4.83±0.06	4.80±0.09	4.82±0.08	4.79±0.07	4.75±0.08	4.81±0.07	4.78±0.04	4.77±0.01
Fenu_AG_Alu_Bag	4.75±0.04	4.71±0.03	4.50±0.03	4.76±0.01	4.35±0.05	4.65±0.02	4.55±0.06	4.52±0.02	4.42±0.03
Fenu_AG_Poly_Bag	3.86±0.06	3.41±0.05	2.89±0.07	3.74±0.01	3.58±0.02	3.29±0.09	3.71±0.06	3.61±0.01	3.42±0.05
BP_CG_Glass_Jar	4.89±0.01	4.86±0.03	4.81±0.03	4.88±0.02	4.83±0.07	4.69±0.03	4.77±0.05	4.47±0.03	4.21±0.01
BP_CG_Plastic_Jar	4.84±0.04	4.81±0.06	4.78±0.01	4.75±0.03	4.66±0.01	4.56±0.07	4.71±0.06	4.67±0.01	4.61±0.02
BP_CG_Steel_Jar	4.85±0.03	4.82±0.03	4.56±0.09	4.86±0.04	4.83±0.06	4.78±0.04	4.75±0.07	4.72±0.02	4.57±0.08
BP_CG_Alu_Bag	4.47±0.04	4.36±0.01	4.33±0.02	4.76±0.01	4.67±0.05	4.51±0.04	4.43±0.07	4.31±0.01	3.88±0.05
BP_CG_Poly_Bag	4.38±0.06	4.27±0.03	4.25±0.01	3.98±0.01	3.79±0.07	3.57±0.03	3.89±0.06	3.66±0.03	3.36±0.02
Fenu_CG_Glass_Jar	4.95±0.06	4.85±0.01	4.65±0.05	4.87±0.06	4.83±0.04	4.76±0.03	4.89±0.07	4.78±0.02	4.73±0.05
Fenu_CG_Plastic_Jar	4.83±0.02	4.81±0.06	4.78±0.01	4.89±0.03	4.56±0.01	3.98±0.09	4.77±0.02	4.65±0.01	4.49±0.07
Fenu_CG_Steel_Jar	4.78±0.04	4.55±0.01	4.23±0.03	4.79±0.05	4.75±0.02	4.61±0.05	4.75±0.01	4.72±0.02	4.59±0.09
Fenu_CG_Alu_Bag	3.98±0.09	3.38±0.05	3.67±0.01	3.85±0.03	3.65±0.01	3.48±0.07	3.57±0.05	3.45±0.01	3.26±0.07
Fenu_CG_Poly_Bag	3.96±0.04	3.80±0.01	3.71±0.07	3.79±0.03	3.58±0.01	3.39±0.08	3.93±0.06	3.34±0.04	3.30±0.02

Table 3 Effect on moisture content in samples stored under normal storage conditions

Sample	Before Grinding	Just After Grinding	1st Month	2nd Month	3rd Month	4rth Month	5th Month	6th Month
BP_AG_Glass_Jar	12.92 ±0.5	12.90 ±0.5	12.88 ±0.6	12.36 ±0.4	12.35 ±0.5	12.36 ±0.6	12.35 ±0.3	12.36 ±0.5
BP_AG_Plastic_Jar	12.92 ±0.5	12.89 ±0.5	12.88 ±0.4	12.64 ±0.5	12.64 ±0.5	12.65 ±0.6	12.65 ±0.4	12.64 ±0.3
BP_AG_Steel_Jar	12.96 ±0.4	12.93 ±0.4	12.90 ±0.4	12.92 ±0.6	12.92 ±0.5	12.91 ±0.5	12.91 ±0.5	12.91 ±0.5
BP_AG_Alu_Bag	12.92 ±0.6	12.90 ±0.5	12.25 ±0.5	11.89 ±0.4	11.89 ±0.4	11.89 ±0.5	11.90 ±0.6	11.90 ±0.6
BP_AG_Poly_Bag	12.92 ±0.3	12.54 ±0.6	12.08 ±0.5	11.94 ±0.6	11.93 ±0.4	11.93 ±0.3	11.93 ±0.5	11.94 ±0.4
Fenu_AG_Glass_Jar	9.54 ±0.5	9.52 ±0.4	10.68 ±0.3	10.66 ±0.4	10.67 ±0.5	10.66 ±0.5	10.67 ±0.3	10.67 ±0.4
Fenu_AG_Plastic_Jar	10.54 ±0.5	10.22 ±0.5	10.23 ±0.3	10.22 ±0.4	10.22 ±0.6	10.23 ±0.4	10.21 ±0.4	10.22 ±0.5
Fenu_AG_Steel_Jar	9.54 ±0.4	9.22 ±0.5	9.82 ±0.6	9.82 ±0.3	9.82 ±0.6	9.81 ±0.6	9.82 ±0.5	9.81 ±0.5
Fenu_AG_Alu_Bag	9.54 ±0.4	8.22 ±0.4	8.23 ±0.5	8.22 ±0.5	8.21 ±0.4	8.22 ±0.6	8.22 ±0.6	8.23 ±0.5
Fenu_AG_Poly_Bag	9.54 ±0.5	8.22 ±0.6	9.06 ±0.5	9.06 ±0.6	9.06 ±0.4	9.07 ±0.5	9.05 ±0.6	9.06 ±0.6
BP_CG_Glass_Jar	13.12 ±0.3	13.03 ±0.6	13.11 ±0.4	13.11 ±0.5	13.10 ±0.6	13.10 ±0.3	13.11 ±0.5	13.10 ±0.3
BP_CG_Plastic_Jar	12.98 ±0.5	12.94 ±0.5	12.68 ±0.5	12.56 ±0.4	12.55 ±0.5	12.55 ±0.4	12.55 ±0.4	12.54 ±0.5
BP_CG_Steel_Jar	13.02 ±0.6	13.00 ±0.5	13.01 ±0.6	13.02 ±0.4	13.02 ±0.5	13.01 ±0.5	13.03 ±0.4	13.02 ±0.4
BP_CG_Alu_Bag	12.92 ±0.5	12.83 ±0.3	12.55 ±0.6	12.56 ±0.5	12.57 ±0.4	12.56 ±0.6	12.56 ±0.5	12.57 ±0.6
BP_CG_Poly_Bag	12.93 ±0.5	12.82 ±0.5	12.36 ±0.4	12.36 ±0.6	12.34 ±0.4	12.35 ±0.4	12.36 ±0.6	12.35 ±0.5
Fenu_CG_Glass_Jar	9.54 ±0.6	8.89 ±0.4	8.90 ±0.4	8.89 ±0.6	8.90 ±0.5	8.91 ±0.5	8.89 ±0.3	8.90 ±0.4
Fenu_CG_Plastic_Jar	9.54 ±0.6	8.88 ±0.4	8.87 ±0.5	8.88 ±0.5	8.87 ±0.4	8.87 ±0.3	8.88 ±0.3	8.88 ±0.6
Fenu_CG_Steel_Jar	9.56 ±0.4	8.87 ±0.5	8.86 ±0.3	8.87 ±0.4	8.87 ±0.6	8.86 ±0.6	8.86 ±0.5	8.87 ±0.3
Fenu_CG_Alu_Bag	9.58 ±0.5	8.89 ±0.5	8.90 ±0.3	8.89 ±0.3	8.90 ±0.3	8.91 ±0.5	8.90 ±0.6	8.89 ±0.5
Fenu_CG_Poly_Bag	9.54 ±0.4	8.83 ±0.3	8.81 ±0.4	8.82 ±0.5	8.83 ±0.5	8.82 ±0.3	8.83 ±0.4	8.82 ±0.4

3.5 Change in weight of fenugreek and black pepper powders

In packed and stored powder over a period of time, there was loss in total mass which might be due to limitations in packaging material, transportation, processing and attack by biological agents. The samples of fenugreek and black pepper powder packed in different packaging materials were weighed for every month to notice any change in its mass (Table 4).

Table 4 Change in powder weight with storage time

Sample	Before Grinding	Just After Grinding	1st Month	2nd Month	3rd Month	4rth Month	5th Month	6th Month
BP_AG_Glass_Jar	250.03 ±0.5	241.02 ±0.4	238.01 ±0.5	235.01 ±0.5	232.01 ±0.6	229.01 ±0.3	226.00 ±0.4	223.00 ±0.6
BP_AG_Plastic_Jar	250.05 ±0.6	240.39 ±0.5	237.38 ±0.4	234.32 ±0.6	231.38 ±0.6	228.37 ±0.3	225.36 ±0.3	222.35 ±0.4
BP_AG_Steel_Jar	250.02 ±0.6	239.61 ±0.5	236.61 ±0.3	233.61 ±0.6	230.61 ±0.4	227.60 ±0.5	224.59 ±0.5	221.57 ±0.4
BP_AG_Alu_Beg	150.01 ±0.4	144.13 ±0.3	141.12 ±0.5	138.12 ±0.4	135.12 ±0.4	132.11 ±0.6	129.11 ±0.6	126.10 ±0.5
BP_AG_Poly_Beg	150.03 ±0.4	142.35 ±0.3	139.34 ±0.5	136.33 ±0.5	133.32 ±0.3	130.33 ±0.5	127.32 ±0.6	124.38 ±0.5
Fenu_AG_Glass_Jar	250.02 ±0.5	245.89 ±0.5	242.87 ±0.5	239.86 ±0.5	236.85 ±0.3	233.84 ±0.4	230.81 ±0.5	227.80 ±0.4
Fenu_AG_Plastic_Jar	250.01 ±0.5	245.94 ±0.6	242.93 ±0.6	239.92 ±0.3	236.92 ±0.5	233.91 ±0.4	230.90 ±0.3	227.80 ±0.3
Fenu_AG_Steel_Jar	250.01 ±0.3	235.46 ±0.6	232.45 ±0.6	237.21 ±0.5	229.44 ±0.5	226.44 ±0.5	223.43 ±0.4	220.41 ±0.3
Fenu_AG_Alu_Beg	150.02 ±0.5	145.03 ±0.5	142.03 ±0.5	139.01 ±0.4	136.01 ±0.6	132.99 ±0.5	129.99 ±0.5	126.98 ±0.5
Fenu_AG_Poly_Beg	150.03 ±0.7	148.19 ±0.4	145.18 ±0.4	142.18 ±0.4	139.17 ±0.5	136.17 ±0.3	133.16 ±0.4	130.16 ±0.4
BP_CG_Glass_Jar	250.04 ±0.6	248.87 ±0.4	245.86 ±0.5	242.85 ±0.5	239.84 ±0.4	236.84 ±0.3	233.83 ±0.3	230.83 ±0.5
BP_CG_Plastic_Jar	250.02 ±0.5	245.02 ±0.4	242.01 ±0.5	239.01 ±0.3	235.99 ±0.4	232.99 ±0.5	229.98 ±0.5	226.92 ±0.5
BP_CG_Steel_Jar	250.01 ±0.4	246.12 ±0.6	243.11 ±0.3	240.11 ±0.5	237.10 ±0.5	234.00 ±0.4	231.09 ±0.6	228.07 ±0.4
BP_CG_Alu_Beg	150.03 ±0.4	142.21 ±0.5	139.19 ±0.3	136.19 ±0.6	133.19 ±0.3	130.17 ±0.4	127.16 ±0.6	124.15 ±0.6
BP_CG_Poly_Beg	150.02 ±0.5	143.02 ±0.3	140.01 ±0.5	137.01 ±0.6	134.00 ±0.3	130.98 ±0.6	127.98 ±0.3	124.97 ±0.5
Fenu_CG_Glass_Jar	250.01 ±0.3	242.46 ±0.3	239.46 ±0.4	236.45 ±0.5	233.45 ±0.5	230.44 ±0.6	227.44 ±0.5	224.43 ±0.5
Fenu_CG_Plastic_Jar	250.01 ±0.3	242.53 ±0.6	239.52 ±0.4	236.52 ±0.4	233.51 ±0.6	230.51 ±0.4	227.50 ±0.4	224.40 ±0.4
Fenu_CG_Steel_Jar	250.03 ±0.5	242.62 ±0.5	239.62 ±0.5	236.61 ±0.4	233.60 ±0.4	230.59 ±0.4	227.59 ±0.6	224.58 ±0.3
Fenu_CG_Alu_Beg	150.01 ±0.6	146.46 ±0.6	143.45 ±0.6	140.40 ±0.3	137.44 ±0.5	134.44 ±0.5	131.44 ±0.5	128.43 ±0.4
Fenu_CG_Poly_Beg	150.01 ±0.5	144.60 ±0.4	141.59 ±0.3	138.59 ±0.5	135.58 ±0.4	132.58 ±0.6	129.58 ±0.4	126.56 ±0.5

3.6 Antioxidant activities of fenugreek and black pepper powder

Antioxidant activity of fenugreek and black pepper powder was determined and it was found that antioxidant activities decreased over a period of time because during long term storage, its natural constituents turned into other compounds and also, some volatile compounds easily escaped away from the ground powders. It can be concluded from Figure 3 that antioxidant property decreased with the storage time. It was also observed that cryogenically ground powder retained higher antioxidant activities[23,24].

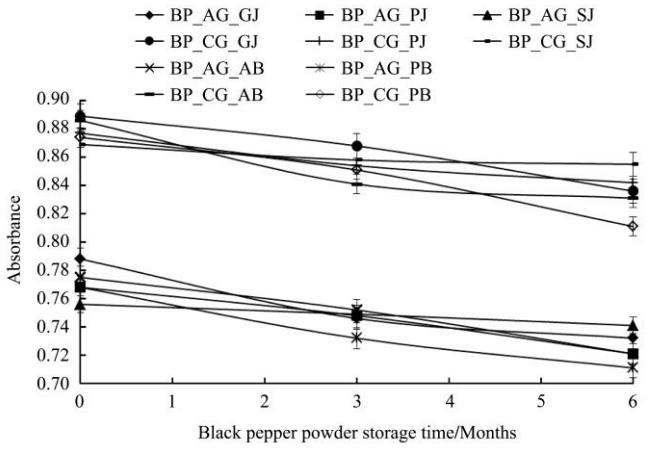

Figure 3 Antioxidant activities of stored black pepper AG and CG powders

3.7 Biological deterioration

Fenugreek and black pepper samples stored in plastic jars were found to be affected by biological agents. Figure 4 shows fenugreek and black pepper powders stored in plastic jars just after grinding. Fenugreek powder was found to be totally eaten up and spoiled by insects whereas black pepper was found to be lusterless, dull and became hard mass with minimal aroma after a period of more than 2½ years. Insects covered the powder fully and most of them were found on the upper surface of the powder. They made hole in powder and made the powder hard by agglomerating (caking) mass having minimal aroma and appealing colour.

a. Fenugreek AM-2 b. Fenugreek Rmt-1 c. Black Pepper

Figure 4 Pictorial view of fenugreek and black pepper samples spoiled by biological agents

4 Conclusions

It was concluded from the present study that powder loses its colour, flavour, odour and aroma value with the storage time at various rate based on type of packaging materials. Antioxidant activities were found to be decreasing with the storage time. Among the ambient and cryogenically ground powders, cryogenically ground powder had higher antioxidant activities. Colour values of ΔL, Δa and Δb were found to be decreasing and also observed that powders were losing appealing effect and freshness over a long period of time. Glass jar and steel jar were found to be better packaging material for studied spices perhaps due to their inertness, compactness and better barrier property. Fenugreek and black pepper powders stored in plastic jars in dry and cool place at room temperature for 2½ years were found to be deteriorated by biological agents. Based on powder quality retention, the order of packaging materials may be as follows: Glass jar > Steel Jar > Aluminum bag > Plastic jar > Poly bag.

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