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Effect of moisture absorber and packaging materials on quality parameters of Jaggery cubes

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Abstract
Jaggery (Gur) industry is one of the old and large agro-processing cottage industries in India. However it has problems related to keeping quality mainly in rainy season. The main problems associated with jaggery storage are liquefaction and deterioration of color. It's storage is highly influenced due to presence of invert sugars and mineral salt which are hygroscopic in nature. This study was undertaken was to evaluate the quality characteristics of jaggery for 180days with different treatments of active packaging, edible coating material and different sizes of high density polyethylene bags. The pH of stored edible coated jaggery with active packaged varied from 5.47 to 5.74 hardness and total viable counts varies from 160.67 to 179.98 and 17 to 27 × 10^3CFU/g and colour difference (ΔE) ranges from 25.01 to 39.26 showed better colour of the product. The hardness decreased with the increased the value of thickness of HDPE bags followed by moisture absorber ($p<0.01$). For good quality jaggery, the following independent variables were recommended as moisture absorber (8g), concentration of CMC and HPMC (1.178 g/ml) and thickness of high density polyethylene bags (197µ). It was concluded from the present study that problems because of absorption of moisture and microbial attack could be overcome using moisture absorber, applying edible coating on jaggery and packing it high density polyethylene bags and storing it under controlled conditions of temperature and relative humidity.

Keywords: Jaggery cubes, active packaging, HDPE, pH, colour difference and hardness

1. Introduction

Jaggery (Gur) is an eco-friendly traditional sweetener prepared from sugarcane juice by thermo-evaporation (Roy, 1951). It contains 80–85 % sucrose, 10–15 % of reducing sugars inclusive of glucose and fructose, 0.25 % of proteins, 0.5 % of fat and 0.6–1 % minerals (Kumar 1999).

It is nutritionally superior to white sugar and has various medicinal properties (Ghosh *et al*. 1998) [2]. About 19.1 % of sugarcane is utilized by the jaggery and khandsari industry in India, producing about 7 million tonnes of jaggery annually (Anon 2005) [1]. The major factor that governs the consumer preference and marketing of jaggery is its external appearance i.e. colour, texture and storability (Kapur and Kanwar 1983) [3]. Jaggery is far complex than sugar, as it is made up of longer chains of sucrose. Hence, it is digested slower than sugar and releases energy slowly and not spontaneously. This provides energy for a longer time and is not harmful for the body. But this does not certify it fit for consumption by diabetics, because ultimately it is sugar. The major problem associated with jaggery storage is the presence of invert sugars and mineral salts which being hygroscopic in nature absorbs moisture particularly during monsoon season when ambient humidity is high and lead to spoilage. During storage, jaggery basically suffers from four types of deterioration: physical, chemical, biological and microbiological. The main problems related to solid jaggery storage are running-off (liquefaction) and deterioration of color during storage (Kunte, 1952). These problems arise due to quick absorption of moisture and microbial attack on jaggery. Therefore, the aim of this study is to evaluate the effect of High Density Polyethylene (HDPE) bags of different sizes, concentrations of hydroxy propyl methyl cellulose (HPMC; E464) and carboxy methyl cellulose (CMC; E466) based edible coating and moisture absorber as an active packaging agent to improve shelf life of jaggery. The moisture absorber (food grade silica gel) absorbs moisture present in the jaggery cubes inside the package to ensure the quality of product during storage and extends its shelf life.

It can also eliminate odor problems and prevent microbial growth in the product. HPMC and CMC based edible coating is known to have desirable barrier properties against moisture, oxygen and gases.

2. Materials and Methods

The packaging material selected for the study based on the availability, cost and barrier properties being the basic elements for any materials to retain the product quality. A stainless steel frame of dimensions 16 x 9 x 1" (L x W x H) was made from (Kumoun steel works and general order supplier, Nagla, Pantnagar). Liquid jaggery poured into mould for making uniform size 1x1x1"jaggery cubes at ambient temperature, after one hour solidified separated from frame and kept into carton for the experiments. The powder form of HPMC and CMC (0.528, 0.8, 1.2, 1.6 and 1.872g/100ml) was taken and mixed with 100 ml distilled water for preparation of edible coating solution. The uncoated jaggery cubes were dipped for 22 to 25 seconds with the help of forceps into the solution and kept them into cleaned aluminum tray for making complex film over the surface of each jaggery cubes, and dried into tray dryer (MSW) at 40 ºC for 3-4 hours, and cooled the material at room temperature (Banerjee and Chen, 1995) and (Anand *et al.* 2017) [6]. Dried coated jaggery cubes kept into different thickness of HDPE bags with moisture absorber (kept into low density foam) and sealed using hand operated sealing machine (MSW), and stored for a period of 180 days.

2.1 pH

pH meter was used for pH measurements. The pH meter was calibrated using pH 7 and pH 4 standard solutions (Ranganna, 1986).

2.2 Hardness

Hardness (Hardness is a measure of degree of resistance offered by a food material) was tested using a hardness tester (Kiya Seisakusho Ltd. Tokyo, Japan) in which jaggery was kept horizontally under the indenter which moved vertically. When the jaggery started to crack then the reading of the tester was recorded. There were two load indicators namely, the black one turned due to pressure and went back to zero when the jaggery broke and the red one remained still after breaking the jaggery indicating the breaking load or jaggery hardness. It is expressed as kg force.

2.3 Total viable counts

One gram of sample was taken by scrapping off surface of stored active packaged edible coated jaggery cubes. Serial dilutions were made by mixing the powdered sample and thoroughly agitating it with 10 ml of autoclaved distilled water in a test tube. The suspension was further used for serial dilution by withdrawing 1 ml from the tube and adding it to 9 ml of the sterile distilled water used as blank. Dilutions were made up to 10 times for each sample. The sterile petriplates (90 mm) were poured with 20 ml of media. On solidification of media, one ml of each diluted sample was withdrawn aseptically from dilutions and placed on the surface of agar petriplate in triplicate. Then samples were spread by the spreader and plates were incubated at 28^{0}C for 2-3 days. The number of Colony Forming Units per gram (CFU/gm) was determined for each jaggery samples**.** Each petri plate was divided into four equal parts and then the colonies were counted in a single part and then multiplied by 4, this gives the total number of colonies in a single petri plate (APHA, 1992).

$$CFU = \frac{\text{Number of colonies X dilution factor}}{\text{Volume of sample}}$$

2.5 Colour difference

Samples were kept on the specimen port (95mm diameter) to cover the full exposed area of the port to the light. All measurements were replicated thrice and the mean readings were taken. The L, a and b values are three dimensions of a measured colour which gives specific colour value of the material. Colour difference (ΔE) indicates the degree of overall colour change of a sample in comparison to colour values of an standard sample having colour values of L*, a*, and b* (Arslan *et al.,* 2010) [8]. Colour difference was calculated using equation gieven below,

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Where, $\Delta L^* = L^*_{fresh\ sample} - L^*_{after\ storage}$, $\Delta a^* = a^*_{fresh\ sample} - a^*_{after\ storage}$ and $\Delta b^* = b^*_{fresh\ sample} - b^*_{after\ storage}$

Since ΔL*, Δa* and Δb* may be positive or negative while the total difference in colour is always positive. The ΔL* is called difference in lightness/darkness, determines lighter when positive and darker when negative Δa* is called difference in red and green axis, it determines redder when positive and greener when negative, and Δb* is called difference in yellow and blue axis, it determines yellower when positive and bluer when negative.

3. Results and Discussion

3.1 Behaviour of independent parameter on responses

Storage studies of edible coated jaggery samples with active packaging agent were conducted at different intervals for 180 days. The quality characteristics of stored edible coated jaggery cubes in active packaging environment were evaluated in terms of pH, hardness (N), total viable count (cfu/gx10^3), and colour difference (ΔE). Statistical analysis was done to evaluate the effect of independent variables viz moisture absorber, concentration of CMC and HPMC and thickness of HDPE bags on various quality parameters considered in this study.

3.2 pH

The sample were analyzed with the help of pH meter at 180 days of storage period the initial pH of active packaged edible coated jaggery cubes of samples 1 to 20 was found in range from 5.4 to 5.56 while in case of control sample it was 5.55. The maximum value of pH was observed to be 5.74 with the combination of moisture absorber (8g). concentration of CMC and HPMC (1.6 g/100ml) and thickness of HDPE bag (200 µm) while the minimum value of pH was found to be 5.47 with the combined effect of moisture absorber (4 g), concentration of CMC and HPMC (0.8g/100ml) and thickness of HDPE bag (100 µm). After 180 days of storage, pH was found to be slightly increased for almost all samples. The reason behind this nominal increased in pH perhaps could be due to less microbial attack and slightly increased in the value of reducing sugar as compared to control sample kept under ambient condition 5.91. No variation in pH of the sample was found.

3.2.1 Statistical analysis of pH

The regression model checked with the values of R^2 of (0.9841), adj-R^2 (0.9697) and pred-R^2 (0.9220) for pH, having least residual error (0.0019) in the fitted quadratic model given in Table 1. Furthermore, the value of adj-R^2 (0.9697) relatively close to the model fitted into the experimental data it implies that the Pred-R^2 of 0.9220 is in reasonable agreement with the Adj-R^2 of 0.9623 because of the difference between Adj-R^2 and Pred-R^2 is less than 0.2. Thus, the model had minimum variability in pH data. The Lack of Fit F-value of 2.95 implies the Lack of Fit is not significant relative to the pure error. There is a 12.45% chance that a Lack of Fit F-value, this large could occur due to noise. Non-significant lack of fit is good and hence the model is fit for pH data. The coefficient of variation of pH was found 0.25% also indicates minimum variability in data fitted in the model. Model was found highly significant (P<0.01). Therefore, second order regression equation was considered to be an adequate for describing the effect of independent variables on pH of stored active packaged edible coated jaggery cubes. At linear as well as quadratic level, it was observed that all moisture absorber, concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose and thickness of HDPE had highly effect on pH at 1% level of significance while no significant effect was found at interactive level.

Table 1: Statistical analysis of pH

Source	df	Sum of Squares	Mean Square	F-Value	p-value Prob > F
Model	9	0.1201	0.0133	68.621	< 0.0001**
X_1	1	0.0342	0.0342	175.812	*< 0.0001***
X_2	1	0.0305	0.0305	157.112	*< 0.0001***
X_3	1	0.0394	0.0394	202.418	*< 0.0001***
X_1X_2	1	0.0002	0.0002	1.029	*0.3344*
X_1X_3	1	0.0002	0.0002	1.029	*0.3344*
X_2X_3	1	0.0008	0.0008	4.115	*0.0700*
X_1^2	1	0.0050	0.0050	25.856	*0.0005***
X_2^2	1	0.0072	0.0072	36.871	*0.0001***
X_3^2	1	0.0060	0.0060	30.894	*0.0002***
Residual error	10	0.0019	0.0002		*0.1652*
Lack of Fit	5	0.0014	0.0003	2.535	< 0.0001**
Pure Error	5	0.0006	0.0001		
Cor Total	19	0.1220			
R^2	0.9841				
Adj R^2	0.9697				
Pred R^2	0.9063				

** at 1% level of significance, * at 5% level of significance. X_1: Moisture absorber, X_2: concentration of CMC and HPMC, X_3: thickness of HDPE bags

The Fig 1 depicts that the effect of thickness of high density polyethylene bags on pH at optimum conditions of moisture absorber (8g) and concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose (1.178g/ml) of stored active packaged jaggery cubes. Slightly changed the pH from (5.61, 66μm) to (5.60, 80μm) after that it gradually increased upto 5.74 with the increased the values of thickness of HDPE bags for reduction of microbial growth in the sample.

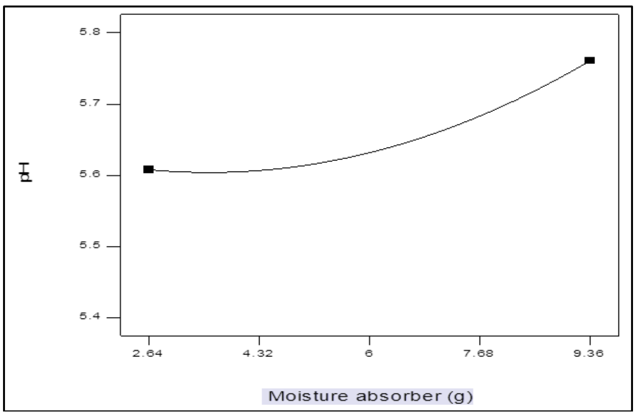

Fig 1: Effect of moisture absorber on pH at optimum points (X_2= 1.178g/ml and X_3 = 197μm)

3.3 Hardness

When samples were stored at zero days in January 2017, minimum and maximum relative humidity and temperature were 49 and 95% and 9 and 23.5^{0}C while sample were analyzed after storage 180 days in June, 2017 then maximum and minimum values of relative humidity and temperature were found to be 89 and 69 % and 32.5 and 24^{0}C. At 180 days storage of samples, the maximum value of hardness was obtained to be 179.98 N with the combination of moisture absorber (6g). concentration of CMC and HPMC (1.2g/100ml) and thickness of HDPE bag (234 μm) while the minimum value of hardness was found to be 160.67 N with the combined effect of moisture absorber (4 g), concentration of CMC and HPMC (1.6g/100ml) and thickness of HDPE bag (100 μm). At 180 days of storage, the hardness was found in range from 160.67 to 179.98 N while in case of control sample it was (198.58N). Similar results were obtained by Anand *et al.* (2017) [6]. At 180 days of storage time, the hardness was found to be nominal decreased not much more variations in the data it was due to high moisture absorber and concentration of CMC and HPMC while in case of control sample was found to be increased during storage periods and hence the sample was discarded due to microbial.

3.3.1 Statistical analysis of hardness

The second order regression model was analyzed with the values of R^2 of (0.8578), adj-R^2 (0.7298) and pred-R^2 (-0.0381) for hardness of the samples, having least residual error (86.97) in the fitted quadratic model. A negative Pred-R^2 implies that the overall mean is a better predictor of hardness than the current model. Model was found highly significant 1% level of significance. At linear level, from Table 2 it was concluded that moisture absorber, concentration of CMC and HPMC and thickness of HDPE bags had highly effect on hardness at 1% level of significance out of them thickness of HDPE bags shows highest effect on the response followed by moisture absorber due to the highest F-value. A very minimum change in hardness were observed due to the effect of moisture absorber and thickness of high density polyethylene bags and creates a protective shield of dry air within enclosed storage area, good sealable property to the sample within package. At interactive level, no significant effect of moisture absorber and concentration of CMC and HPMC was obtained whereas moisture absorber and thickness of HDPE bags had significant ($p<0.05$) effect on hardness during storage. At quadratic level, no significant effect of moisture absorber, concentration of CMC and HPMC was found while thickness of high density polyethylene bags had highly significant ($p<0.01$) on hardness at 180 days of storage.

Table 2: Statistical analysis of hardness

Source	df	Sum of squares	Mean square	F-value	p-value Prob > F
Model	9	524.62	58.29	6.70	0.0032**
X_1	1	116.34	116.34	13.38	0.0044**
X_2	1	46.35	46.35	5.33	0.0436*
X_3	1	124.73	124.73	14.34	0.0036**
X_1X_2	1	0.00045	0.00045	0.000052	0.9944
X_1X_3	1	67.98	67.98	7.82	0.0189*
X_2X_3	1	0.46	0.46	0.053	0.8226
X_1^2	1	4.31	4.31	0.50	0.4977
X_2^2	1	3.57	3.57	0.41	0.5360
X_3^2	1	168.00	168.00	19.32	0.0013**
Residual error	10	86.97	8.70		
Lack of Fit	5	81.04	16.21	13.68	0.0061
Pure error	5	5.92	1.18		
Cor total	19	611.58			
R^2	0.8578				
Adj-R^2	0.7298				
Pred-R^2	-0.0381				

** at 1% level of significance, * at 5% level of significance. X1: Moisture absorber, X2: concentration of CMC and HPMC, X3: thickness of HDPE bags

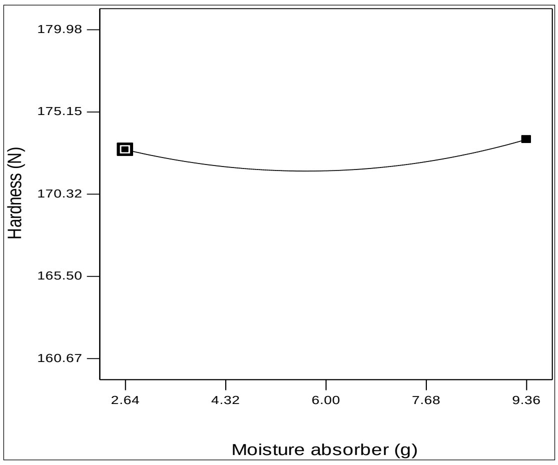

Fig 2: Effect of moisture absorber at optimum points (X_2 = 1.178g/ml and X_3 = 197µm)

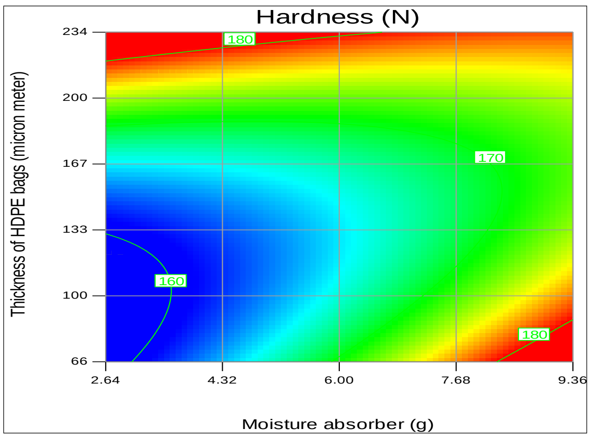

Fig 3: Contour plot between moisture absorber and thickness of HDPE bags at optimum points (X_2 = 1.178g/ml)

The contour plot has drawn in Fig 2 shows the effect of moisture absorber on the hardness (N) of active packaged edible coated jaggery cubes at optimum points of concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose (1.178g/ml) and thickness of high density polyethylene bags (197µm). The pattern shows that hardness of the sample first decreased slightly from 173.25 to 172.55N due to increased moisture absorber from 2.64 to 5.8g after that it slightly increased with the values of moisture absorber. The Fig 3 drawn between moisture absorber and thickness of high density polyethylene bags at optimum conditions of concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose (1.178g/ml) to evaluate their effect on hardness of stored active packaged edible coated jaggery samples. The pattern shows that only significant effect of thickness of high density polyethylene bags on the hardness, initially decreased trend was observed in the sample due to best sealing property for the sample during storage.

3.4 Total viable counts

At zero days, the samples had 1×10^3 (cfu/g) and this total viable counts found to be increased till 180 days of storage period. The reason behind this nominal increased could be due to the samples having coating of carboxy methyl cellulose and hydoxy propyl methyl cellulose, thickness of HDPE bags and moisture absorber were subjected for all the samples. Because of all these factors (CMC and HPMC, thickness of HDPE bags and moisture absorber) especially edible coating (CMC and HPMC) up to some extent successfully controlled the microbial attack. In case of control samples total viable counts was found higher than uncontrolled samples it means that sample without any coating and active packaging materials got affected by environmental conditions and got changed due to environmental conditions.

3.4.1 Statistical analysis of total viable counts

The second order regression model was checked with the values of R^2 of (0.9446), adj-R^2 (0.8947) and pred-R^2 (0.6048) for total viable counts (cfu/gx10^3) of the samples, having least residual error (12.54) in the fitted quadratic model. At linear level, from Table 3, it was observed that the effect of moisture absorber, concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose and thickness of high density polyethylene bags were obtained highly significant ($p<0.01$) out of them thickness of high density polyethylene bags had highest significant at 1% level of significance followed by moisture absorber on the total viable counts in the sample during 180 days storage. It indicates that no significant growth of bacteria was observed by making proper shield on the surface of jaggery cubes. At interactive level, no significant effect of moisture absorber and concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose followed by moisture absorber and thickness of HDPE bags was observed whereas concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose and thickness of HDPE bags had significant ($p<0.05$) effect on total viable counts. At quadratic level, effect of moisture absorber was significant ($p<0.05$) while no significant effect of concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose and thickness of HDPE bags.

Table 3: Statistical analysis of total viable counts

v	df	Sum of squares	Mean square	F-value	p-value Prob > F
Model	9	213.66	23.74	18.94	< 0.0001**
X_1	1	21.32	21.32	17.00	0.0021**
X_2	1	21.28	21.28	16.98	0.0021**
X_3	1	140.60	140.60	112.15	< 0.0001**
X_1X_2	1	1.13	1.13	0.90	0.3658
X_1X_3	1	3.13	3.13	2.49	0.1455
X_2X_3	1	10.12	10.12	8.08	0.0175*
X_1^2	1	12.44	12.44	9.92	0.0103*
X_2^2	1	0.70	0.70	0.55	0.4736
X_3^2	1	4.80	4.80	3.83	0.0790
Residual error	10	12.54	1.25		
Lack of Fit	5	11.70	2.34	14.04	0.0058
Pure error	5	0.83	0.17		
Cor total	19	226.20			
R^2	0.9446				
Adj-R^2	0.8947				
Pred-R^2	0.6048				

** at 1% level of significance, * at 5% level of significance.X1: Moisture absorber, X2: concentration of CMC and HPMC, X3: thickness of HDPE bags

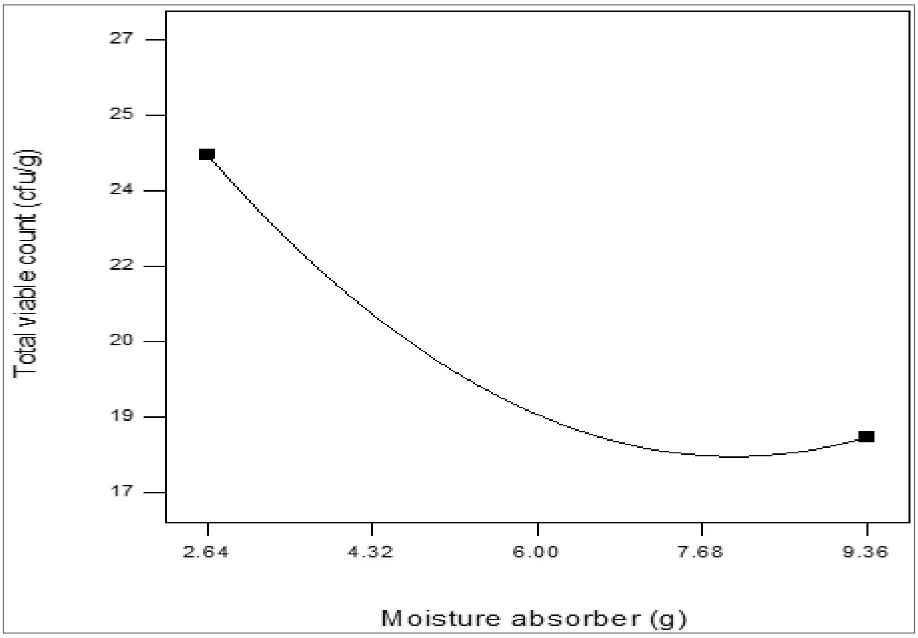

Fig 4: Effect of moisture absorber at optimum points (X_2 = 1.172g/ml and X_3 = 197µm)

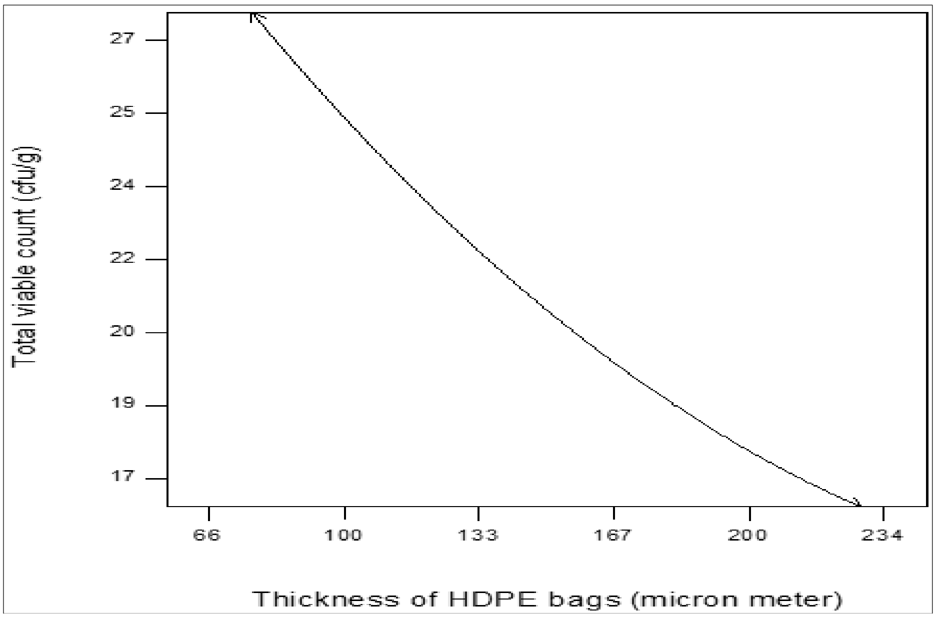

Fig 5: Effect of thickness of HDPE bags at optimum points (X_1 = 8g and X_2 = 1.178g/ml)

At linear level, the contour plot has drawn in Fig 4 shows the variation in moisture absorber with total viable counts at optimum conditions of concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose (1.178g/ml) and thickness of high density polyethylene bags (197µm) of the samples. The pattern shows that total viable counts decreased gradually from 24.5 x 10^3 to 18 x 10^3cfu/g with increased the values of moisture absorber from 2.64 to 7.68g of stored active packaged jaggery sample. It was due to development of dry conditions within packages at ambient conditions. At linear level, the Fig 5 depicts that the highly significant effect of thickness of high density polyethylene bags on total viable counts due to develop a protective shield of dry air within enclosed package and prevent from mechanical shock by forming a complex matrix on the surface of jaggery cubes at optimum points of moisture absorber (8g) and concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose (1.178g/ml). The graph reveals that the total viable counts decreased with increased the values of thickness of density polyethylene bags which indicates good storage life of the product.

3.5 Colour difference (ΔE)

At linear level, from Table 4 it was clear that the effect of moisture absorber and concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose were found significant ($p<0.05$) on colour difference while thickness of high density polyethylene bags had no significant. It indicates that no deterioration of colour of coated jaggery was observed during storage by making a uniform matrix on the surface. At interactive level, the effect of concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose and thickness of HDPE bags had highest significant ($p<0.01$) in comparison to the combined effect of moisture absorber and concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose on colour difference. The effect of concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose was observed significant ($p<0.01$) at quadratic level while thickness of HDPE bags was significant at 5% level of significance.

Table 4: Statistical analysis of colour difference

Source	df	Sum of squares	Mean square	F-value	p-value Prob > F
Model	9	189.30	21.03	11.12	0.0004**
X_1	1	11.65	11.65	6.16	0.0324*
X_2	1	17.38	17.38	9.19	0.0126*
X_3	1	7.85	7.85	4.15	0.0689
X_1X_2	1	40.14	40.14	21.23	0.0010**
X_1X_3	1	8.28	8.28	4.38	0.0628
X_2X_3	1	54.92	54.92	29.04	0.0003**
X_1^2	1	0.24	0.24	0.13	0.7300
X_2^2	1	35.02	35.02	18.52	0.0016**
X_3^2	1	10.39	10.39	5.49	0.0411*
Residual error	10	18.91	1.89		
Lack of Fit	5	5.08	1.02	0.37	0.8523
Pure error	5	13.83	2.77		
Cor total	19	208.21			
R^2	0.9092				
Adj-R^2	0.8274				
Pred-R^2	0.7117				

** at 1% level of significance, * at 5% level of significance.X1: Moisture absorber, X2: concentration of CMC and HPMC, X3: thickness of HDPE ba

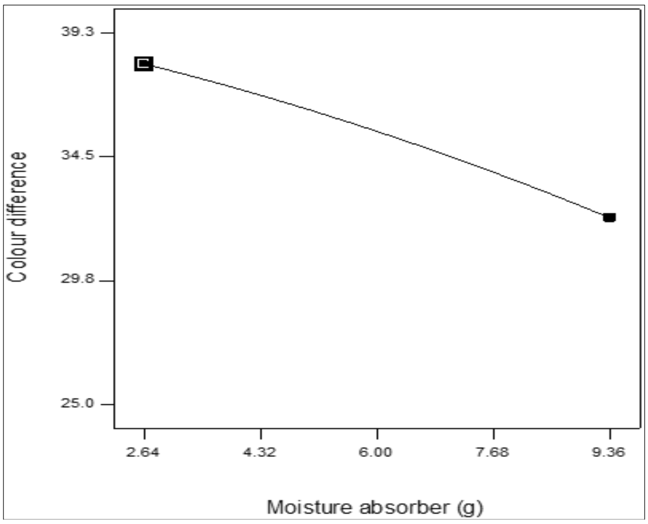

Fig 6: Effect of moisture absorber on colour difference at optimum points (X_2 = 1.178g/ml and X_3 = 197µm)

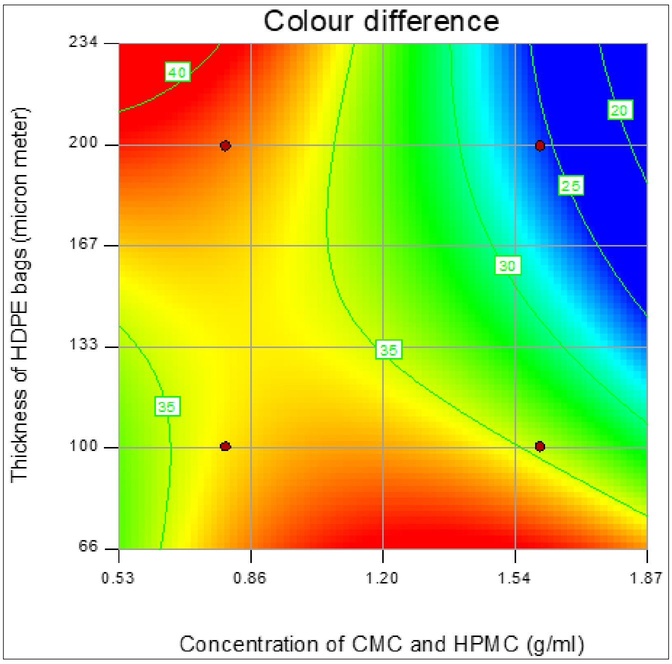

Fig 7: Effect of concentration of CMC and HPMC and thickness of HDPE bags on colour difference at optimum point (X_1 = 8g)

At linear level, the contour had drawn in Fig 6 establish a relationship between moisture absorber and colour difference (ΔE) at optimum conditions of concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose (1.178g/ml) and thickness of high density polyethylene bags (197µm). The pattern shows that the colour difference decreased gradually from 38.2 to 32.5 with increases the values of moisture absorber from 2.64 to 9.36g due to the good sealing property between environment and product. The minimum change in colour difference as compare to control indicates no deterioration in colour of stored jaggery cubes during entire storage study. In Fig7, the pattern reveals that the colour difference decreased from 35 to 20 with increased the values of concentration of carboxy methyl cellulose and hydoxy propyl methyl cellulose from 0.53 to 1.87g/ml because it make uniform matrix on the jaggery cubes due to which no water activity in the sample was observed and retained the colour.

4. Conclusion

From the present studies, as jaggery would be a healthier alternative for sweetness due to absence of fat and higher mineral content. However it has many problems related to keeping quality. The main problems are liquefaction of jaggery during rainy season and deterioration of color during storage. All these problems could be overcome using best combination of packaging technique with moisture absorber (8g), edible coating of CMC and HPMC (1.178 g/ml) and then packing it in high density polyethylene bags (197micron). At these conditions, physical, chemical and microbiological deterioration was negligible after storage study.

5. Acknowledgments

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