

Colour Changes in Jaggery Cubes under Modified Atmosphere Packaging in Plastic Film Packages

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Abstract

Jaggery cubes made from sugarcane (variety: CoJ64) was stored under modified atmosphere packaging (70% N₂+30% CO₂), at ambient conditions in low density polyethylene (LDPE), polypropylene (PP), polyethylene terephthalate (PET), and laminated aluminum film packages for a period of 210 days, to enhance the shelf life and to evaluate the effect of modified atmosphere packaging (MAP) on moisture content, phenols, color, reducing sugars, and texture of jaggery. MAP resulted in colour changes in the original yellowish red colour of jaggery under different plastic films. Instead of conventional CIELAB colour space system utilizing only L*, a* and b* values, the colour changes were analyzed as per L*C*h* colour space system using lightness, chroma and hue angle values, to evaluate the final hue (colour). On 210th day of storage, the samples kept in all the films were dark, but the intensity of darkness was least for PET film. The best retention of colour was observed for PET film under MAP. Further, the sensory and visual analysis of jaggery samples during entire storage period was in line with the results obtained from L*C*h* colour space diagram.

Keywords: Jaggery; Storage; Modified atmosphere packaging; Plastic films

Introduction

Jaggery (also known as gur) is a natural, traditional sweetener, made by the concentration of sugarcane juice. It is a traditional unrefined non centrifugal sugar consumed in Asia, Africa, Latin America and the Caribbean. It contains all the minerals and vitamins present in sugarcane juice, and that is why it is known as healthiest sugar in the world. In some of the South American countries, it is known as *Panela*. It is a concentrated product of cane juice, without separation of the molasses and crystals, and can vary from golden brown to dark brown in colour. It is rich in important minerals like salts: 2.8 g/100 grams, whereas only 300 mg/kg is obtained in refined sugar. Magnesium present in jaggery strengthens our nervous system and helps to relax our muscles, gives relief from fatigue and takes care of our blood vessels. It also along with selenium acts as an antioxidant, with property to scavenge free radicals from our body. The potassium and low amount of sodium present in it maintain the acid balance in the body cells, and also combats acids and acetone and controls our blood pressure. Jaggery is rich in iron, and helps to prevent anemia. It also helps to relief tension; takes care of asthma, as it has anti allergy properties. It is good for migraine and at the time of post pregnancy, it has great benefits to perform to remove all clotted blood from the body of women, within post 40 days after the birth of a baby [1].

The quality and price of jaggery is governed by its external features like colour and texture. A quality jaggery is one having golden yellow colour, hard in texture, crystalline in structure, sweet in taste, less in impurities and low in moisture [1]. The quality of jaggery is influenced by the variety of cane grown, quantity of fertilizers used, quality of irrigation water and the method of clarification, processing time, storage condition and packaging methods adopted. Grading of jaggery is done based on physical properties like colour and texture, and chemical properties like sucrose content, reducing sugar, moisture, water insoluble material, etc. Presently, jaggery is graded at national level on Agmark system of solid jaggery grading (based on physical characteristics) and BIS standard IS: 2923 [1].

Darkening of jaggery colour during storage under ambient condition is problem faced by jaggery manufacturers and traders, since dark colour jaggery is not preferred by consumers. Darkening may be due to physical, chemical, biological or microbiological deterioration of jaggery. Reducing sugar, poly phenols, organic non sugars, proteins and iron are main factors affecting colour of jaggery [2].

The estimates show that 5-10% of stored jaggery valued about Rs. 1000 crore, is lost during monsoon annually [3]. The traditional packaging methods for storage in vogue (e.g. inside a blanket of bhusa or wheat straw, cloth lined with polyethylene sheet, aluminum foil, plastic containers, earthen pots and jute bag), give far from satisfactory results, and in these days of acute food shortage, the need for evolving an effective packaging method must be regarded as a national importance. Also at retail level, the jaggery is sold in open and under unhygienic condition. Hence, there is need to evolve suitable packaging technique to enhance shelf life and maintain quality of jaggery. Modified Atmosphere packaging (MAP) is a well established technique in which the gases surroundings of a product are altered, resulting in an atmospheric condition different from that of air [4]. The interaction between product, barrier material and environment determines the gas composition inside the package [5]. MAP improves the product quality, freshness and increases the shelf-life of the product, as well as provides convenience to the consumer and adds value to the product. In this study, the influence of different gaseous concentration on chromatic changes in jaggery cubes made from sugarcane (variety: CoJ64) was

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studied, during storage under 70% N₂+30% CO₂ at ambient temperature in low density polyethylene (LDPE), polypropylene (PP), polyethylene terephthalate (PET) and laminated aluminum film packages, for a period of 210 days.

Materials and Methods

Good quality matured sugarcane variety CoJ 64 was harvested closed to the ground and cleaned off dry leaves, trashes, green tops, roots and mud clods, and transported to jaggery making unit at Indian Institute of Sugarcane Research, Lucknow, India. The cane was then crushed in horizontal crusher and juice was transferred to settling tank covered with thick layered cloth, to filter small particle impurities. The juice was then allowed to remain in the tank for one hour so that heavy impurities settles down due to gravity, and the clean juice was then pumped into open pans kept on triple pan furnace. The juice was then preheated for clarification. Clarification of juice is required to make light coloured jaggery. It eliminates impurities in suspension, colloidal and colouring compounds by accumulation. The preheated juice was then transferred to second pan where deola extract (@45g 0100l juice) was added to the juice to increase coagulation. The juice was then boiled and concentrated. When the boiling and concentrating juice reached striking point temperature (127°C), it was transferred to wooden cooling pan, where it was mixed with help of ladles. The slurry was then poured into moulding frame to get jaggery cubes of 2.5 cm size. The cubes were naturally cooled and dried. 200 g of jiggery cubes were packed in selected films *viz.* LDPE, PP, PET, and laminated aluminum film. The samples were stored at ambient temperature for 210 days.

Colour Evaluation

Conventionally, all conceivable colours can be located using Commission Internationale de l'Enclaireage (CIE) L*, a*, b* colour space system, abbreviated as CIELAB [6], which is specified by three perpendicular axes. The L* indicates intensity of colour, *i.e.* lightness which varies from L*=100 for perfect white to L*=0 for black. 'a*' and 'b*' are chromaticity dimensions, which give understandable designations of colour, *i.e.* the value of 'a*' measured redness when positive, grey when zero, and greenness when negative, and the value of 'b*' measured yellowness when positive, grey when zero, and blueness when negative. These coordinates pinpoint the measured colour in a three-dimensional colour space. In this system, although lightness is correctly pointed out using L*, the other two parameters, *i.e.* a* and b* are merely chromatically coordinates, which needs to be further manipulated to arrive at the appropriate terms namely, hue and chroma. L*, a* and b* values were determined at four places over the entire surface of the jaggery; using a Hunter Lab scan (Model Miniscan XE plus, Hunter associated, USA), in such a way that the sample was placed in close contact with the lens of the instrument, so that the light which falls on the sample should reflect back and no light is transmitted to the surroundings and values obtained were averaged. The instrument was first calibrated with a standard white plate and black plates provided along with equipment before taking observations. The instrument data was analyzed to evaluate the colour changes during the entire storage period, as per L* C* h* colour space system which uses cylindrical coordinates, as compared to rectangular coordinate system of CIELAB colour space. In this system, L* indicate lightness and is similar to L* of L* a* b* colour space system, C* is chroma and h* is the hue angle. The chroma, hue angle and yellowing index are represented in terms of a* and b*, as per the equations.

$$\Delta E^* = \sqrt{\Delta L^{*2} - \Delta a^{*2} - \Delta b^{*2}} \quad (1)$$

$$\text{hue angle}(h^*) = \tan^{-1}(b^* / a^*) \quad (2)$$

The colour comparison between the reference and sample objects in this system is evaluated in terms of hue and chroma difference, *i.e.* ΔH^* and ΔC^* . The ΔC^* is chroma difference between the reference and sample objects, ΔH^* is evaluated from the following relationship

$$\Delta H^* = \sqrt{\Delta E^{*2} - \Delta L^{*2} - \Delta C^{*2}} \quad (3)$$

Where ΔE^* , ΔL^* and ΔC^* refer to the size of the colour difference, lightness difference and chroma difference, respectively between the reference and sample objects.

The ΔE^* can be calculated as per the equation as under

$$\Delta E^* = \sqrt{\Delta L^{*2} - \Delta a^{*2} - \Delta b^{*2}} \quad (4)$$

Where Δa^* , Δb^* refer to the change in the chromatically coordinates for reference and sample objects.

Phenolic content

The concentration of total phenols was determined as per McGuire [6], using Folin Ciocalteu reagent. One gram of jaggery sample was extracted with 10 ml of methanol: water (50:50, v/v) solution. Then 0.5 ml of diluted (1:10) extract was mixed with 5 ml of Folin Ciocalteu reagent (1:10 diluted with distilled water) and 4 ml of aqueous Na₂CO₃ (1M). The mixtures were allowed to stand for 15 min and the optical density of the mixtures was measured against the blank at 765 nm, with the help of a UV-Vis spectrophotometer. The Standard curve was prepared using 0, 50, 100, 150, 200, 250 µg solutions of gallic acid per ml of methanol: water (50:50, v/v). Total phenol values were expressed in terms of the standard reference compound as gallic acid equivalent (mg/100 g of sample).

Reducing sugars

0.1 ml of aliquot was taken in a reducing sugar tube. 1.9 ml of distilled water was added to the solution. Then 1 ml of alkaline copper reagent was added to it. Then the tubes were placed in boiling water for 10 minutes. The tubes were cooled and 1 ml of asrenomolybdate reagent was added, and the volume was made to 10 ml with water. Absorbance was measured at 620 nm.

Sensory evaluation

The stored samples were analyzed for sensory evaluation by a three member panel on 9 point hedonic scale. The selected panel was briefed with the sensory characteristics that were to be judged, and also with the available scales according to which the samples were to be rated. The panel members were requested to assemble at one place prior to evaluation, as the samples were required to be judged immediately when opened. Each member was provided with the sensory evaluation rating scales, based on which the rating was given to various samples. The average values of the ratings given by all the members were then calculated and used for further analysis.

Statistical analysis

One-way analysis of variance (ANOVA) and multiple comparisons (Fisher's least significant-difference (LSD) test) were used to evaluate the significant difference among different treatments at $p < 0.05$, using a statistical package (Statgraphics Plus, Statpoint Inc., USA). All the experiments were replicated thrice and analyzed entire data obtained during the experiment was expressed as means \pm standard deviation.

Results and Discussion

Total phenols

Total phenols play an important role in imparting dark colour to jaggery. Under MAP, the overall change in total phenols was 273.82 mg/100 g, 213.84 mg/100 g, 248.76 mg/100 g and 129.87 mg/100 g for LDPE, PET, PP and laminated film, respectively. In laminated, the increase in total phenols was 0.46 times as compared to 1.97 times in LDPE. The initial rate of increase of increase of total phenols was slow, but increased significantly towards the end of storage duration. The total phenol content at the end of the storage period was minimum in laminated film (Figure 1). This may be due to the fact as the gas permeability and moisture permeability was minimum for laminated film, hence, there was least ingress of air and moisture into the package, as compared to other films. In jute bag, the phenol content increased almost three times after 210 days of storage.

ANOVA revealed that there was significant ($p < 0.05$) effect of packaging material, storage atmosphere and duration on phenol content of jaggery. During the entire duration, there was progressive increase in the phenol content in all the treatments. Among the packaging material, the variation in the mean was least in laminated film closely followed by PET.

Reducing sugars (%)

Reducing sugar also plays a major role in imparting colour to jaggery. Less is reducing sugar, better is the colour. Changes in reducing sugar content in jaggery packed in LDPE, PET, PP and laminated, under MAP over entire storage period, is presented in figure 2. The maximum increase in reducing sugars was 25.81% in control sample.

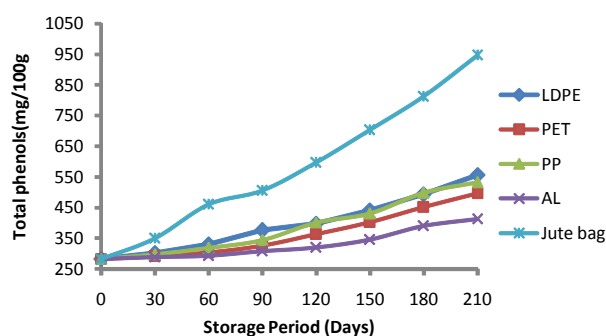


Figure 1: Variation in phenolic content of jaggery packed in packaging films under MAP.

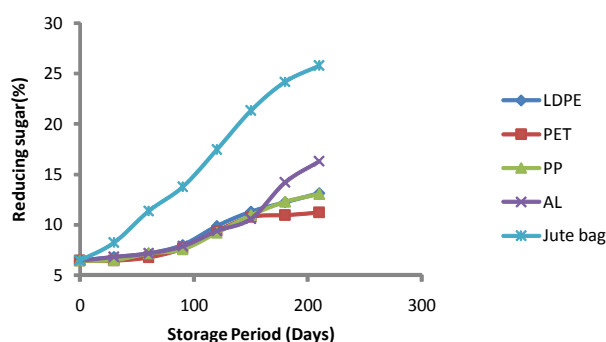


Figure 2: Variations in reducing sugar content in jaggery under MAP.

Minimum increase of 11.23% was attained in PET. All the films showed a similar trend. The variation till 90th day of storage showed a non significant increase among different films. The increase in the reducing sugar was significant after 150th days of storage. The performance of PET was better in controlling the increase of reducing sugar after 210th day of storage. Under MAP, significant difference in variation of reducing sugars was observed after 150th day of storage. The increase was maximum for laminated film (16.29%) and minimum for PET (11.23%). ANOVA revealed that there was significant ($P < 0.05$) effect of MAP, package and storage period, on reducing sugar of stored jaggery. Within the package, PET has least mean of 9.578, indicating that it effectively controlled the changes in reducing sugar content, followed by PP. Similar trend in reducing sugar was also observed by Mandal et al. [3] and Chand et al. [7].

Colour changes

The total changes at the end of 210th day of storage with references to fresh jaggery samples used, were evaluated by representing ΔC^* , ΔH^* in the first quadrant of the $L^* C^* h^*$ colour space diagram (Figure 3); the decrease in value of ΔC^* was minimum for first 60 days of storage for MAP. The -ve sign indicated that the colour became duller with storage period. Minimum ΔC^* values obtained was -2.94 for LDPE, -1.11 for PET, -2.41 for PP, and -0.78 for laminated aluminum film. ΔC^* , change in jute bag showed a maximum value of -3.78, indicated more dullness in colour. In jute bag, changes in ΔC^* showed increasing positive values, indicating increase in brightness of colour till 120th day of storage.

Under MAP, all packages showed a decreasing trend. The ΔC^* was constant for initial period of 60 days for all the films. ΔC^* was least, -0.78 for laminated film, followed by PET, PP and LDPE. Maximum ΔC^* change of -2.94 was observed in LDPE. Two distinct trends were observed after 60 days of storage. PET and laminated followed one trend and remained close to the reference point, i.e. the change in ΔC^* was minimum. LDPE and PP followed another trend and remained away from the reference point, i.e. the change in ΔC^* was maximum.

The changes in ΔH^* remain confined to first quadrant (Figure 4), which meant that towards the end of storage, the jaggery samples kept under MAP after losing their original colour, remained between yellow and red. There was increase in ΔH^* values with storage time in all the treatments. The initial change was less till 60th day of storage, indicating that original hue was maintained till 60th day. In the control sample, there was steady increase in ΔH^* value till 150th day, followed by sudden increase on 210th day of storage. The increase was maximum for LDPE and minimum for PET, indicating that PET film was able to retain more of the original colour after the end of the storage. The increase was linear in all the films till 150th day of storage.

The direction of colour difference for different treatments with

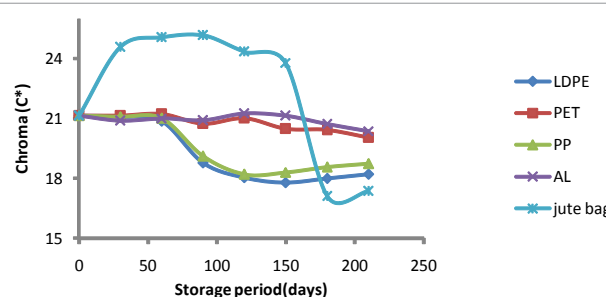
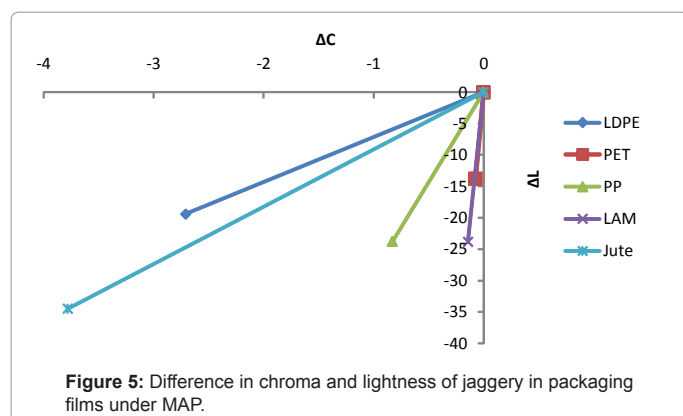
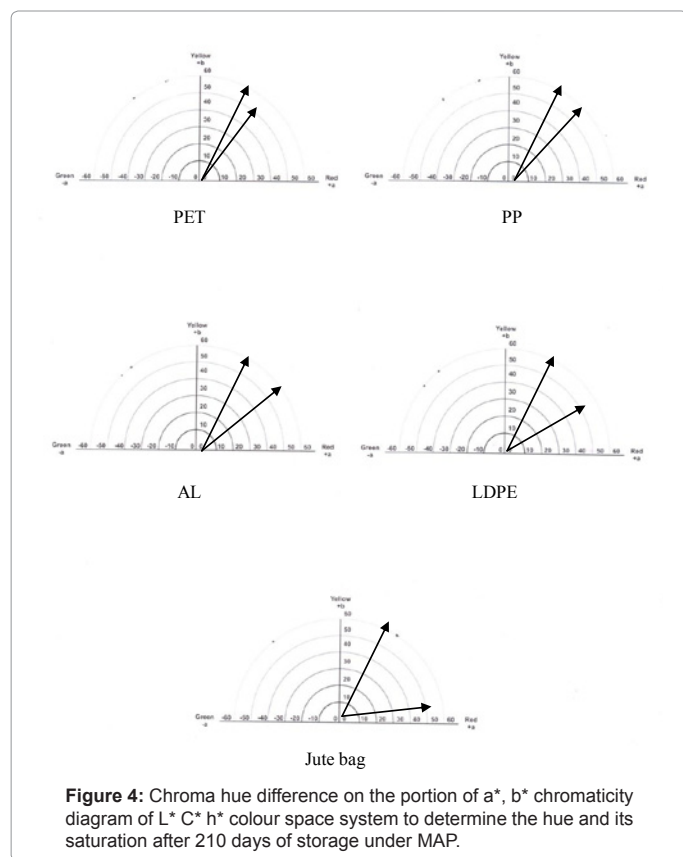


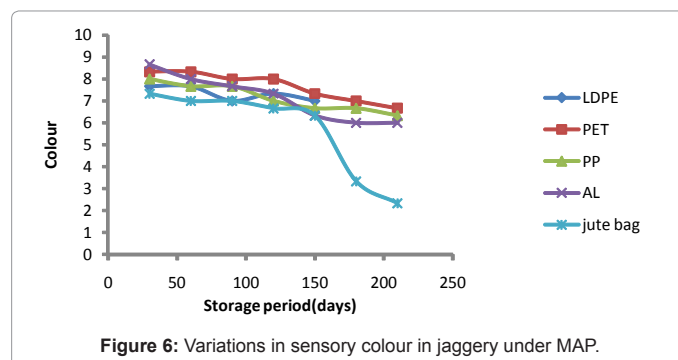
Figure 3: Changes in chroma difference (ΔC^*) of jaggery in different packaging films under MAP.



respect to fresh jaggery was evaluated by means of ΔC^* , ΔL^* (Figure 5). It lied in the third quadrant of colour space system, which is indicative of darkness. The intensity of darkness was highest for control. The darkening was least for PET. The direction of colour was observed to be dark for all films under MAP. The degree of colour difference was represented by means of additional modifiers, such as slightly dark for LDPE packages and slightly deep for laminated packages. The control could be described as moderately dark.

Sensory evaluation

The shelf-life of the jaggery is influenced largely by the sensory quality parameters such as visual appearance (colour), texture, taste and flavor, which suggest its suitability for human consumption; regardless of instrumentally determined parameters. The results of the study suggest that PET and PP films in retaining the original sensory



characteristics, till the end of storage period. No off-odour was observed in any of the packages.

The colour in all the samples showed a progressive decrease with storage time (Figure 6). In control sample, abrupt decrease in colour after 150th day of storage was observed. Under MAP, the colour change was least. The decrease in the colour score was more in PP and laminated, after 120 days of storage. PET film maintained the colour most, followed by laminated. The taste of the samples in PET liked more compared to others under MAP. The taste of the samples in PET and PP after 210th day of storage, was liked by the panels, whereas it was disliked for laminated and jute bag.

The texture of jaggery showed an initial increase on 60th day, and then showed a decreasing trend over the entire period in MAP. Texture of jaggery in laminated film decreased with time of storage, and was disliked after 120th day of storage in all MAP. PET was able to maintain the texture till end of the storage, followed by PP.

Overall, for the jaggery stored under different packaging treatment for 210 days, it may be concluded on the sensory basis that PET film was able to retain the original sensory characteristics of jaggery, till the end of storage. The overall acceptability scores were maximum for MAP.

In conclusion, improper storage often leads to dark colour of jaggery, leading to reduction in market value. Results revealed that MAP stored jaggery was much superior in terms of maintenance of low phenol and reducing content, as compared to control. Although MAP has different effects on phenol and reducing content which could be quantified objectively, however, the exact chromatic changes expressed in terms of hue and its associated attributes, including the difference from the originally stored jaggery, could be successfully expressed through analysis of colorimetric data, using $L^* C^* h^*$ colour space diagram. Which could point out significant difference among different treatments and can pinpoint the exact colour attained at the end of storage? The best retention of colour was observed for PET film under MAP. Further, the sensory and visual analysis of jaggery samples during entire storage period was in line with the results obtained from $L^* C^* h^*$ colour space diagram, and indicated that PET film under MAP (70% N_2 +30% CO_2) was most suitable for maintaining the chromatic quality of jaggery cubes.

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