India is the second largest producer of sugarcane next to Brazil and the jaggery industry is one of the most important cottage industries in India. Jaggery is used for the preparation of traditional foods and many ayurvedic medicines. India exports 1.73 million tonnes of jaggery to countries like Bangladesh, Malaysia, Sri Lanka, Saudi Arabia, U.S.A., Indonesia, U.K., Nepal, etc., contributing Rs. 217 crores to the Indian economy (Apeda, 2009).

Jaggery is specially beneficial for people who are anemic, cannot eat or tolerate meat, suffering from frequent muscle cramps, tension or soreness, pregnant or experiencing pre-menstrual syndrome (PMS) symptoms and those who have eaten too much salt can balance out their diets with jaggery (Jadhav et al., 2005). It is also proved that jaggery is used in the treatment of bronchial or lung infections and research has shown to possibly offset some of the lung damage caused by silicosis.

Although jaggery is known for its healthy sweetness, due to poor or un-hygiene processing practices, it is losing its quality and turning towards the hazardous part in our routine diet and also the improper packaging and storage methods have lead to quality loss. Jaggery is packaged traditionally under different packaging materials like paddy straw, banana leaves, gunny bag, polythene sheet, etc., which possess poor barrier properties against moisture, light, air, etc., leading to spoilage or deterioration of jaggery quality. It has been reported that more than 10% of jaggery produced in the country, worth Rs. 40 crore, is lost every year due to product deterioration (Mandal et al., 2006).

Khanna and Chakravarti (1948) conducted studies on storage of jaggery and reported that there was more than 10 per cent loss in sucrose, 50 per cent increase in acidity, 2 per cent increase in the moisture content and 20 to 30 per cent increase in the total colour change in the jaggery stored in open atmosphere between August and October months compared to jaggery stored under closed condition inside the blankets.

Some of the common methods adopted for the jaggery storage are use of earthen pots, over dry leaves or wooden planks in rooms, in gunny bags and in earthen pots hung from
None of these are completely satisfactory for preserving jaggery in good conditions particularly during the wet and humid monsoon conditions (Khanna and Chakravarti, 1948).

The results obtained from study conducted at IISR Lucknow (1994) revealed that use of sodium hydro sulphite, alum and phosphoric acid for making jaggery increased the reducing sugar from 9.7 to 12.1 per cent and consequently lead to poor storability of jaggery (Banerji et al., 1994).

Moisture studies of jaggery packaged in different packaging material like polyethylene, perforated polyethylene, cellophane paper showed that moisture loss was almost equal in jaggery packaged in perforated polyethylene and unpacked control followed by cellophane paper and polythene without perforation (Anwar et al., 1994).

Ramya et al. (2007) assessed the storage quality in commercially available jaggery with different packaging materials and reported that there was an increase in moisture content, reducing sugar and change in colour in jaggery packaged in polyethylene and jute bags. Storage containers of food grade polyethylene proved to be better for storage of jaggery without affecting the quality of jaggery.

In view of facts presented above, proper packaging method needs to be developed to keep the jaggery under good condition for short period of time. Therefore, a research study was conducted to assess the quality of jaggery packaged in different packaging materials and stored under different conditions for a specified period of time with a focus to suggest better packaging and storage methods for farmers.

**Experimental Methods**

The different packaging material selected for the study were based on the availability, cost and barrier properties being the basic elements for any materials to retain the product quality. The packaging material used (Fig. A) and treatments imposed are given below:

- **P₁** - Tri layer - aluminum foil (AL) + polyester (PR) + polyethylene (PE) - 800 guage
- **P₂** - Double layer - polyester (PR) + polyethylene (PE) - 400 guage
- **P₃** - Single layer - polyethylene (PE) - 400 guage

**Packing Type:**

- **M₁** - Ambient packaging
- **M₂** - Vacuum packaging

The production of jaggery was done in a farmer’s jaggery processing plant at Malaipeppankuttai village, Namakkal District, Tamil Nadu and the jaggery was prepared under good hygiene condition by following the scientific principles and methods, keeping in mind some of the basic practices like proper filtration and clarification, removal of scum at different intervals and transferring the syrup at striking point to the molds, maintenance of cleanliness in de-molding area, etc.

After air cooling, jaggery (approx. 300 g) was placed in different packaging material selected and packed under ambient condition and in vacuum condition by heat sealing and vacuum packaging, respectively. The packed jaggery was stored for 10 weeks in dark. The quality analysis was done at weekly intervals. Standard methods were followed to determine the jaggery quality:

**Ash content and porosity:**

The ash content and porosity of the jaggery was determined using the formula (Asokan and Rupa, 2008):

$$\text{Ash content (\%)} = \frac{\text{Weight of ash}}{\text{Weight of jaggery}} \times 100$$

$$\text{Porosity (\%)} = \frac{\text{Initial volume of kerosene (cc)} - \text{Final volume of kerosene (cc)}}{\text{Volume of 20 g of jaggery (cc)}} \times 100$$

**Moisture content:**

Moisture content was estimated gravimetrically by following the procedure outlined by AOAC (Anonymous, 1980).

**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 applied.

The change in the colour (ΔE) was observed using a Hunter Lab Colourimeter and the values of L, a, b were used to measure the colour change and the microbial load was analyzed using the plate count method.

The quality parameters like reducing sugar, total reducing sugar and sucrose were determined using the methods followed by Anonymous (2005) and Ranganna (1997).

Net rendement (NR):

Net rendement value is a quality parameter specific to jaggery and is based on the proportion of sucrose, reducing sugar and ash content. Net rendement values were computed according to Indian trade conventions as described by Roy (1951).

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\text{Net rendement} = [\text{Sucrose} \% - (\text{Reducing sugar} \% + 3.5 \times \text{Ash, } \%)]
\]

Sensory evaluation:

The organoleptic evaluation of the product (pongal) was done for colour, flavour, texture, taste and overall acceptability (Ranganna, 1997). Nine-point Hedonic scale was used as sensory evaluation score card to bring out the inherent characteristics acceptability of particular product.

EXPERIMENTAL FINDINGS AND ANALYSIS

The jaggery produced (Fig. 1) was subjected to biochemical analysis before storage and after packaging in different packaging materials and following different packaging methods. The samples were taken as per the weekly requirement and stored jaggery quality was analyzed (Table 1).

During storage, different quality parameters like colour, hardness, sucrose, reducing sugar, moisture content, microbial load (bacteria) and porosity of jaggery samples were determined at weekly intervals.

Colour:

The results showed that the colour changed gradually and recorded maximum L value of 48.9 for the jaggery packaged in Al+PE+PR and sealed under vacuum condition and minimum value of 45.8 for the jaggery packaged in PE at ambient packaging. The decrease in the ‘L’ value indicated the turning of jaggery colour towards black and increase in ‘a’ value indicated increase in redness. Among the different packaging materials used, the jaggery packaged in Al+PE+PR under vacuum condition recorded minimum change in total colour value (6.69) after ten weeks of storage and jaggery packaged in PE at ambient packaging recorded a maximum change in total colour value (11.75) which was about 2075.92 per cent compared to the initial colour value before storage (Fig. 2).

Fig. 1 : Jaggery prepared under different treatments

Fig. 2 : Effect of packaging material, packaging conditions and storage duration on total colour of jaggery

Hardness:

During storage, it was observed that the effect of packaging methods on hardness of the jaggery packaged in different packaging materials was distinguishable. After first

| Table 1 : Quality parameters of jaggery before packaging |
|-------------------------------|-----------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Colour value                  | Hardness (kg)   | Sucrose (%)    | Reducing sugar (%) | Microbial load x 10^3 (cfu/g) | Moisture content (% db) | Porosity (%) | Ash content (%) | Net rendement value (Grade) |
| L    | a    | b    |      |                 |                   |         |                |                 |
| 53.9 | 9.77 | 42   | 19.0 | 84.3            | 4.5              | 7.53   | 18.6           | 4.32            | 64.78 (A2)   |
week of storage the jaggery samples of different treatments recorded gradual decrease in hardness value (Fig. 3). The jaggery packaged in multi-layer film namely Al+PE+PR exhibited maximum hardness value during entire period of storage compared to other treatments and recorded a value of 16 kg (15.7 % reduction) and the jaggery packaged in PE at ambient packaging recorded a reduction of 31.5 per cent after 10 weeks of storage.

**Microbial load:**

The microbial analysis showed that, the presence of microbial load was less in vacuum packaged jaggery compared to ambient packaged, irrespective of packaging material used. The jaggery stored in Al+PE+PR recorded a microbial load of 4.1x10^2 cfu/g at the end of first week of storage period and 4.4x10^2 cfu/g at the end of tenth week of storage. Among the different treatments, single layered PE was contaminated with higher microbial load both in ambient air and vacuum packaging conditions (Fig. 4). Singh et al. (2009) reported a microbial load value of 1.3 x10^6 and 4.8 x10^6 cfu/g in commercially available jaggery after fifteen and thirty days of storage under open atmospheric condition. The present study showed the better effectiveness of the use of suitable packaging material and technique for storage of jaggery.

**Moisture content:**

Irrespective of the packaging material used and packaging conditions adopted, the moisture content of jaggery was within 8 per cent (db) only five weeks of storage (Fig. 5). Thereafter, the moisture content started increasing and recorded a maximum value of 11.65 in PE packaged in ambient and a minimum value of 8.55 per cent in Al+PE+PR under vacuum packaging after ten weeks of storage. Benerji et al. (1994) reported a similar trend of increase in moisture content of jaggery with increase in storage period.

**Reducing sugar:**

The reducing sugar content increased in all the treatments, but at different rates based on the micro environment of each treatment (Fig. 6). When compared to all other treatments, jaggery packaged in PE in ambient packaging recorded high reducing sugar and lowest was observed in AL+PR+PE under vacuum condition. Ramya et al. (2007) also observed similar results with the increase in reducing sugars from 10.36 per cent to 24.66 per cent in the commercially available samples stored under traditional method for three months, which is in line with the results obtained in the present study.
Sucrose content:
The sucrose content of jaggery stored at ambient and vacuum packaging in PE was 83.4 and 84.0 per cent, respectively, after first week of storage, and decreased gradually and reached a value of 78.06 and 78.65 per cent, respectively, after ten weeks of storage (Fig. 7). In contradiction to the above, the sucrose content was maintained fairly at higher level in the jaggery stored in Al+PE+PR under vacuum condition (84.30 %) after first week and 81.95 per cent after ten weeks of storage period. Khanna and Chacravarthi (1948) has observed the sucrose content loss was more than ten per cent in jaggery stored under open atmospheric condition over a period of one month, that proves the effect of use of AL+PE+PR over reduction in sucrose content during storage of 4.51 per cent (4.3 per cent increase over fresh jaggery) after ten weeks of jaggery storage.

Sensory evaluation:
Sensory evaluation was carried out by preparing “Pongal”- a traditional sweet prepared (Fig. 9) using jaggery, raw rice, ghee, cashew, resins, cardamom and green gram. The mean value of different quality traits of sensory evaluation, namely, colour and appearance, flavour, texture, taste and overall acceptability is presented in Table 2.

**Conclusion:**
The study clearly revealed that packaging of jaggery produced under a good hygienic condition and packaging in single layer, two layers and triple layers of packaging material and then sealing hermetically (with air) and under vacuum condition (without air) minimised the quality deterioration during the short term storage of ten weeks over the traditional packaging and storage methods. Among the two packaging types, the vacuum packaging restricted changes on different
quality traits of jaggery compared to ambient packaging. Among the different packaging material evaluated, the triple layer packaging material performed better compared to single and double layer packaging material in minimizing the quality loss of jaggery after packaging and storage.

LITERATURE CITED

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