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EFFICACY OF A COATING COMPOSED OF CARBOXYMETHYL CELLULOSE AND WHEY PROTEIN CONCENTRATE TO CONTROL THE QUALITY OF JAGGERY

Ritesh Mishra*, P K Omre, Khan chand, Sanjay Kumar, Ankur Singh Bist
Department of Agricultural Sciences and Engineering, IFTM University, Moradabad
Department of Post Harvest Processing and Food Engineering, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand University of Horticulture and Forestry,
Department of Food Technology, Uttaranchal University, Dehradun
Department of Computer Science, KIET, Ghaziabad

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ABSTRACT
This study evaluated the efficacy of coating composed of Carboxymethyl Cellulose and Whey Protein Concentrate on the storage characteristics and storage quality conditions of coated jaggery for 15 weeks. The edible coating was based on five different levels of Carboxymethyl cellulose (0.5%, 1%, 1.5%, 2%and 2.5%) and Whey protein concentrate (2%, 4%, 6%, 8% and 10%).The results indicate that the storage of jaggery were modified and improved by coating. The statistical data revealed that different treatment of jaggery samples significantly affected the pH, reducing sugar, total microbial count and optical density. The reducing sugar, optical density, total viable count and mould count increased significantly as the storage period increased. However, moisture content and pH followed decreasing pattern during the storage. The result of the study concluded that coating of jaggery sample could help in retaining the desirable moisture upto some extent. Also it can be concluded that problem related to keeping quality of jaggery could be overcome by applying edible coating based on carboxymethyl cellulose and whey protein concentrate.

KEYWORDS: Edible coating, Carboxymethyl cellulose, Storage, Whey protein concentrate.

INTRODUCTION
Gur (Jaggery) is a natural, traditional sweetener made by the concentration of sugarcane juice and is known all over the world (FAO 2007) in different local names (Thakur 1999). It is a traditional unrefined non-centrifugal sugar consumed in Asia, Africa, Latin America and the Caribbean. Containing all the minerals and vitamins present in sugarcane juice, it is known as healthiest sugar in the world. India is the largest producer and consumer of jaggery. Out of total world production, more than 70% is produced in India. (Rao etal 2007). In India, of the 300 Mt of sugarcane produced, 53% is processed into white sugar, 36% into jaggery and khandsari, 3% for chewing as cane juice, and 8% as seed cane (Singh etal 2011). Jaggery and khandsari have withstood competition protecting farmers' interests besides meeting ethnic demands. Processes and equipments have been developed for quality solid, liquid and powder jaggery. Liquid jaggery has been commercialized. The organic clarificants developed help to retain jaggery as organic food.

Sugarcane-based jaggery production is one of the oldest processing industries**,** contains about 0.4% protein, 0.1% fat, 8 mg/100 g calcium, 0.4 mg/100 g phosphorous, 11.4 mg/100 g iron, 0.6–1.0% total minerals and 3830 cal/g energy (Wood 1978). Boiling sugarcane juice is the second important step in the processing of cane for Jaggery/Gur manufacturing. Jaggery/Gur quality and storability often depend on effectiveness of juice clarification. The demand for jaggery is steadily growing many folds in the urban, rural and semi-urban areas. 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 are because of absorption of moisture and microbial attack. (Rao 1973) found that jaggery from mature cane recorded less reduction in quality parameters under cold storage compared to jaggery from immature and over aged cane. Fermentation brought about by yeasts and complex biochemical degradation caused by moulds is the usual forms of microbial deterioration. Moisture uptake resulting from exposure to humid atmosphere either during handling or storage is primarily responsible for most of the storage ills. Physically, it destroys the texture through dissolution and liquefaction. It also dilutes the sugars and lowers the sweetness. Chemically, it promotes inversion of sucrose which in turn leads to loss of texture, structure and body hardness. Moisture gain also encourages microbial infection and degradation. Jaggery also becomes more hygroscopic at higher temperatures (Verma 1985). Drying of jaggery to reduce its initial moisture content is essential for storage (Baboo and Ghosh 1985).Although many packaging materials have been studied with the aim of increasing shelf life, no data are yet available on applying edible coating and packaging for a similar purpose. Extensive research in the area of edible coating has paved the way for different effective edible films and coatings. The purpose of the application of edible films or coatings is to protect the food from microbial decay. Therefore, the purpose of the present study is to evaluate the effect of Whey Protein Concentrate (WPC) and Carboxy methyl cellulose (CMC) based edible coating to improve shelf life of jaggery. WPC and CMC based edible coating is known to have desirable barrier properties against moisture, oxygen and gases.

NUTRITIONAL VALUE AND USES OF JAGGERY

It is rich in important minerals (*viz.*, Calcium-40-100 mg,Magnesium-70-90 mg, Potassium-1056 mg, Phosphorus-20-90 mg, Sodium-19-30 mg, Iron-10-13 mg, Manganese-0.2-0.5 mg, Zinc-0.2- 0.4 mg, Copper-0.1-0.9 mg, and Chloride-5.3 mg per 100 g of jaggery), vitamins (viz., Vitamin A-3.8 mg, Vitamin B1-0.01 mg, Vitamin B2- 0.06 mg, Vitamin B5-0.01 mg, Vitamin B6-0.01 mg, Vitamin C-7.00 mg, Vitamin D2-6.50 mg, Vitamin E-111.30 mg, Vitamin PP-7.00 mg), and protein-280 mg per 100 g of jaggery, which can be made available to the masses to mitigate the problems of mal nutrition and under nutrition. The micronutrients present in the jaggery possess antitoxic and anti-carcinogenic properties (Sahu and Paul 1998). It has moderate amount of calcium, phosphorous and zinc, so it helps to optimum health of a person along with all its benefits, purifies the blood and prevents rheumatic afflictions and bile disorders and thus helps to cure jaundice.

MATERIALS AND METHODS

Results of experimental studies conducted in the Department of Post Harvest Process and Food Engineeringto investigate the effect of levels of WPC and CMC edible coating on jaggery during storage. Fresh jaggery samples were prepared at jaggery manufacturing unit situated at Bhurarani village, Rudrapur. Jaggery was prepared by extracting juice from sugarcane variety 2684 and HD 2824. Whey protein concentrate and Carboxymethyl cellulose were procured from R. K. Scientific Laboratory, Rudrapur. Glycerol was procured from M/S Himedia Laboratories (Haldwani). Low density polyethylene (LDPE) packets (thickness 150 microns) of standard size (half kg) were procured from local market of Rudrapur. The experimental design was applied after selection of ranges. Five levels of WPC (2%, 4%, 6%, 8% and 10%) and CMC (0.5%, 1%,1.5%, 2% and 2.5%) were taken. Twenty five experiments were performed according to full factorial design. Experiments were conducted in triplicate. As per experimental design whey protein concentrate and carboxymethyl cellulose are dissolved in 100 ml distilled water and mix thoroughly to form uniform solution. The solution is denatured at 90°C on water bath for 30 minutes to provide functionality to edible film. The solution is cool down to room temperature in chilled water. Four percent glycerol is added to solution as plasticizer and mix thoroughly. Then prepared content will again be reheated at 50°C for 10 minutes then cooled to room temperature. Analysis of all the stored jaggery samples was determined using standard procedure. Analysis of moisture content and ash content (AOAC 1984), reducing sugar (DNS method), total viable count and mould count (APHA 1992). The difference in quality parameters and acceptability scores of the product were determined statistically using analysis of variance (ANOVA) technique. The data obtained were analyzed using SPSS software.

RESULT AND DISCUSSION

It was observed that initial pH content of jaggery samples was within the range of 5.58 to 5.76. The pH in jaggery samples in all treatments decreases up to 12 week which might be associated with decrease in relative humidity from 60 to 48 percent. Reducing sugar of jaggery was initially found 12.07 to 12.37 percent. After 15th week the reducing sugar content ranged from minimum of 18.15 (T14, T23, T25) to a maximum of 22.84 (Control). There was almost constant increase in reducing sugar in all treatments during storage. The moisture content of jaggery samples was initially observed in range of 12.10 to 13.72 percent which was much higher than the requirement of 5 to 7% as per BIS (Anonymous 1990). The moisture content of jaggery sample in all treatments followed decreasing trend up to 12th week of storage which might be associated with decrease in relative humidity and increase in temperature during storage (Table 4) simultaneously while there was sharp increase in moisture content of jaggery samples in all treatments during 15 week of storage. The changes in colour in terms of optical density of jaggery sample during storage of 15th weeks revealed that initially the sample were golden brown in colour but the colour become dark brown by the end of storage period in all the treatment (Table 1). It is evident that browning in terms of optical density increased gradually with the progress of storage in all the treatment. Coating of jaggery samples with edible coating significantly ($p<0.01$) affected optical density. The initial color in terms of optical density was in range of 0.282 to 0.284 but optical density of jaggery samples in all treatments after 15th week of storage was in the range of minimum 0.302 (T24, T25) to a maximum of 0.364 (Control) which clearly indicated that control sample became much darker than other treatments which may be due to faster inversion of sucrose and edible coating could have helped to retain desirable light color up to some extent. The changes in total viable count of jaggery samples during storage of 15th week (Table 2) indicated that the initial TVC (total viable count) in terms of colony forming unit (Cfu g-1) in the treatment was 2.16×10^3 to 2.32×10^3. It was observed from the storage study that total viable count followed increasing trend from initial 0 week to 15th week of storage period. At the end of storage weeks the maximum colonies were found 7.6×10^3 (Control) and minimum colonies were 5.20×10^3 (T20, T24, T25). The initial yeast/mold count of jaggery samples in terms of colony forming unit (Cfu g-1) in treatments was 3.6×10^2. It was observed from the storage study that yeast/mold count followed increasing trend from initial 0 week to 15th week of storage in all treatment. At the end of storage weeks the maximum colonies were found 8.8×10^2 (Control) and minimum colonies were 7.20×10^2 (T9, T10, T14, T15, T18, T19). Coating of jaggery samples with edible coating significantly ($p<0.01$) affected total viable count and mould count. The initial hardness in terms of force required in Newton (N) to compress the sample completely was in the range of 11.08 to 11.12 in all the treatment (Table 3). It was observed from the storage study that hardness followed an increasing trend from initial 0 week to 12th week of storage period while there was a decrease in hardness in the 15th week of storage study. After 15th week of storage there was difference in hardness found as compared to initial 12 week due to increase in humidity. In control hardness was reduced to 28.2 from 38.2 and in another treatment there were slight decrease in hardness as compared with hardness found in 12th week. Coating of jaggery samples with edible coating significantly ($p<0.01$) affected hardness. This can be observed coating of jaggery samples could help upto some extent in retaining the texture of jaggery. Thereafter hardness was decreased in 15th week of storage; it could possibly due to sudden increase in humidity. Maximum decrease in hardness was found in the control while minimum was found in (T23, T25) as compared to the hardness in 12th week of storage. The sensory evaluation was done for liking of jaggery samples on the basis of color, taste, flavor, texture, aroma and appearance and overall acceptability score (OAA) was calculated. A panel of 10 sensory panelists drawn from amongst the students and staff of various departments were selected to evaluate the samples using 9-point Hedonic scale. The sensory characteristics color, appearance, flavor, texture, taste and overall acceptability of jaggery samples were recorded.

pH

It was observed that initial pH content of jaggery samples was with in the range of 5.58 to 5.76**.** The pH in jaggery samples in all treatments decreases up to 12 week which might be associated with decrease in relative humidity from 60 to 48 percent **(Annexure I).** Thereafter sharp increase in pH from minimum 5.58 (Treatment 10) to maximum 5.66 (control) which may be due to sharp increase in humidity (84 percent) during 15 week. The ANOVA of pH in jaggery samples at 0 week and after 3 week of storage shows that the factor CMC (week) had a significant effect as calculated F value (F_{cal}) is more than tabulated F value (F_{tab}) at 5 % level of significance. It means CMC is responsible for change in pH of jaggery samples upto 3 weeks of storage. Effect of WPC and influence of their interaction had non-significant effect on pH of jaggery samples. ANOVA of pH in jaggery samples after 3 weeks upto 12 weeks of storage shows that the factor WPC and CMC had a significant effect on pH as F value (F_{cal}) is more than tabulated F value (F_{tab}) at 1 % level of significance while influence of their interactions had non-significant effect on pH as calculated F values (F_{cal}) are less than tabulated F values (F_{tab}) for both 1% and 5% level of significant. It can be observed from the ANOVA that after 15 weeks of storage WPC had a significant effect on pH at 1 % level of significance while CMC had non- significant effect on pH. Also influence of their interactions had non-significant effect on pH for both 1% and 5% level of significance.

			pH					
Treatments	**WPC (%)**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	0	0	5.58	5.58	5.5	5.4	5.36	5.66
1	2	0.5	5.58	5.58	5.5	5.41	5.36	5.66
2	4	0.5	5.58	5.58	5.5	5.41	5.36	5.66
3	6	0.5	5.58	5.58	5.52	5.42	5.38	5.62
4	8	0.5	5.62	5.62	5.56	5.46	5.4	5.62
5	10	0.5	5.64	5.64	5.58	5.48	5.37	5.62
6	2	1.0	5.58	5.58	5.52	5.42	5.37	5.62
7	4	1.0	5.58	5.58	5.52	5.42	5.37	5.62
8	6	1.0	5.58	5.58	5.52	5.42	5.42	5.64
9	8	1.0	5.64	5.64	5.58	5.48	5.45	5.58
10	10	1.0	5.66	5.66	5.59	5.5	5.37	5.6
11	2	1.5	5.58	5.58	5.52	5.42	5.38	5.6
12	4	1.5	5.58	5.58	5.54	5.46	5.38	5.6
13	6	1.5	5.58	5.58	5.54	5.46	5.45	5.64
14	8	1.5	5.64	5.64	5.59	5.5	5.49	5.64
15	10	1.5	5.66	5.66	5.62	5.54	5.38	5.6
16	2	2.0	5.58	5.58	5.52	5.43	5.42	5.6
17	4	2.0	5.58	5.58	5.56	5.48	5.42	5.6
18	6	2.0	5.58	5.58	5.56	5.48	5.52	5.64
19	8	2.0	5.64	5.64	5.62	5.54	5.56	5.64
20	10	2.0	5.66	5.66	5.66	5.58	5.48	5.64
21	2	2.5	5.62	5.62	5.58	5.52	5.49	5.64
22	4	2.5	5.62	5.62	5.62	5.54	5.49	5.64
23	6	2.5	5.62	5.62	5.62	5.54	5.6	5.6
24	8	2.5	5.72	5.72	5.72	5.66	5.6	5.6
25	10	2.5	5.76	5.76	5.76	5.68	5.36	5.6

Table no. 1 Changes in pH of Jaggery samples during storage

Reducing Sugar

It was observed from storage study that the reducing sugar increased as storage period increased. The increase in reducing sugar content in jaggery may be due to inversion of sucrose into glucose and fructose. After 15 week the reducing sugar content ranged from minimum of 18.15 (Treatment 23, 14 & 25) to a maximum of 22.84 (Control). There was almost constant increase in reducing sugar in all treatments during storage. The ANOVA of reducing sugar in jaggery samples upto 15 weeks of storage shows that the factor WPC and CMC had a significant effect as calculated F value (F_{cal}) is more than tabulated F value (F_{tab}) at 1 % level of significant.

			Reducing Sugar (%)					
Treatments	**WPC (%)**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	**0**	**0**	12.07	13.08	15.74	18.62	20.15	22.84
1	**2**	**0.5**	12.07	13.08	15.74	18.62	20.15	22.84
2	**4**	**0.5**	12.07	13.08	15.74	18.62	20.15	22.84
3	**6**	**0.5**	12.07	13.08	15.74	18.62	20.15	22.84
4	**8**	**0.5**	12.07	13.08	15.74	18.62	19.2	20.15
5	**10**	**0.5**	12.07	13.08	15.37	17.43	19.42	20.15
6	**2**	**1**	12.07	13.08	15.74	18.62	19.42	20.15
7	**4**	**1**	12.07	13.08	15.74	18.62	19.42	20.15
8	**6**	**1**	12.07	13.08	15.51	17.19	19.2	20.15

9	**8**	**1**	12.07	12.86	15.34	17.19	18.62	19.42
10	**10**	**1**	12.37	12.72	14.51	17.19	18.62	19.42
11	**2**	**1.5**	12.07	13.08	14.51	17.19	18.62	19.42
12	**4**	**1.5**	12.07	13.08	14.51	17.19	18.62	19.42
13	**6**	**1.5**	12.07	13.08	14.51	17.19	17.43	19.2
14	**8**	**1.5**	12.07	13.08	14.28	16.44	17.43	19.2
15	**10**	**1.5**	12.37	12.87	14.28	16.44	17.43	18.62
16	**2**	**2**	12.37	13.08	14.51	17.19	17.43	18.62
17	**4**	**2**	12.07	13.08	14.51	17.19	17.43	18.62
18	**6**	**2**	12.07	13.08	14.51	17.19	17.43	19.2
19	**8**	**2**	12.07	12.86	14.51	16.88	17.19	19.15
20	**10**	**2**	12.07	12.62	14.28	16.44	17.19	18.62
21	**2**	**2.5**	12.07	12.68	14.28	16.88	17.19	18.62
22	**4**	**2.5**	12.07	12.68	14.28	16.88	17.19	18.62
23	**6**	**2.5**	12.07	12.68	14.28	16.88	17.19	18.15
24	**8**	**2.5**	12.37	12.62	14.28	16.44	17.19	18.15
25	**10**	**2.5**	12.37	12.62	14.28	16.44	20.15	18.15

Table no. 2 Changes in Reducing Sugar of Jaggery samples during storage

Moisture Content

It was observed from the storage study that moisture content followed decreasing trend from initial zero week to 12 week of storage period week in all treatment This may be due to forming a thick CMC-WPC based film which lowers oxygen permeability and reduces the moisture content (Hong and Krochta 2003). The moisture content of jaggery sample in all treatments followed decreasing trend up to 12 week of storage which might be associated with decrease in relative humidity and increase in temperature simultaneously while there was sharp increase in moisture content of jaggery samples in all treatments during 15 week of storage. The ANOVA of moisture content in jaggery samples upto 15 weeks of storage shows that the factor WPC and CMC had a significant effect as calculated F value (F_{cal}) is more than tabulated F value (F_{tab}) at 1 % level of significant.

			Moisture content (% wb)					
Treatments	**WPC (%)**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	**0**	**0**	13.72	13.72	11.72	8.05	6.09	11.36
1	**2**	**0.5**	13.72	13.72	11.72	9.05	7.22	11.36
2	**4**	**0.5**	13.72	13.72	11.72	9.05	7.22	11.36
3	**6**	**0.5**	13.86	13.86	11.72	9.15	7.15	11.36
4	**8**	**0.5**	13.72	13.72	11.72	9.15	7.15	10.86
5	**10**	**0.5**	12.71	12.71	11.36	9.15	7.62	10.86
6	**2**	**1**	12.71	12.7	10.86	9.05	7.22	11.36
7	**4**	**1**	12.1	12.1	10.86	9.05	7.22	11.36
8	**6**	**1**	12.1	12.1	10.86	9.05	7.43	11.36
9	**8**	**1**	12.1	12.1	10.86	9.05	7.43	10.36
10	**10**	**1**	12.86	12.86	11.36	9.3	7.59	10.36
11	**2**	**1.5**	12.71	12.71	10.86	9.15	7.59	11.36
12	**4**	**1.5**	12.71	12.71	11.36	9.15	7.59	11.36
13	**6**	**1.5**	12.1	12.1	11.72	9.15	7.62	11.36
14	**8**	**1.5**	12.1	12.1	11.72	9.72	7.62	10.86

15	**10**	**1.5**	12.1	12.1	11.72	10.35	7.69	10.86
16	**2**	**2**	12.86	12.71	10.86	9.68	7.62	11.36
17	**4**	**2**	12.71	12.71	11.36	9.72	7.62	11.36
18	**6**	**2**	12.71	12.71	11.36	10.15	7.83	10.86
19	**8**	**2**	12.7	12.7	11.72	10.35	7.83	11.72
20	**10**	**2**	13.16	13.16	12.71	10.86	8.05	11.38
21	**2**	**2.5**	13.16	13.16	12.1	10.35	7.85	11.72
22	**4**	**2.5**	13.42	13.42	12.1	10.35	7.85	11.72
23	**6**	**2.5**	13.16	13.16	12.1	10.35	7.85	11.72
24	**8**	**2.5**	13.42	13.42	12.71	10.86	8.05	11.84
25	**10**	**2.5**	13.42	13.42	12.71	11.36	8.15	11.84

Table no. 3 Changes in Moisture content of jaggery samples during storage

Optical Density

The initial color in terms of optical density was in range of 0.282 to 0.284 but optical density of jaggery samples in all treatments after 15 week of storage was in the range of minimum 0.302 (Treatment 24 & 25) to a maximum of 0.364 (Control) which clearly indicated that control sample became much darker than other treatments which may be due to faster inversion of sucrose and edible coating could have helped to retain desirable light color up to some extent. After 15 weeks of storage it was found that effect of WPC and CMC had significant effect on optical density at 1% level of significance. Also it was observed that the influence of their interactions had significant effect on optical density after 15 weeks of storage as calculated F values (F_{cal}) are more than tabulated F values (F_{tab}) for 1% level of significance.

			Absorbance at 540 nm					
Treatments	**WPC (%)**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	**0**	**0**	0.282	0.29	0.298	0.306	0.319	0.364
1	**2**	**0.5**	0.282	0.29	0.298	0.306	0.319	0.324
2	**4**	**0.5**	0.282	0.29	0.298	0.305	0.318	0.322
3	**6**	**0.5**	0.282	0.29	0.298	0.305	0.318	0.322
4	**8**	**0.5**	0.282	0.29	0.298	0.305	0.318	0.322
5	**10**	**0.5**	0.282	0.29	0.298	0.305	0.318	0.322
6	**2**	**1**	0.282	0.29	0.298	0.306	0.317	0.319
7	**4**	**1**	0.282	0.29	0.298	0.307	0.317	0.319
8	**6**	**1**	0.282	0.29	0.298	0.305	0.317	0.319
9	**8**	**1**	0.282	0.29	0.298	0.305	0.316	0.318
10	**10**	**1**	0.282	0.29	0.298	0.305	0.316	0.318
11	**2**	**1.5**	0.282	0.29	0.298	0.305	0.317	0.319
12	**4**	**1.5**	0.282	0.29	0.298	0.305	0.317	0.319
13	**6**	**1.5**	0.282	0.29	0.298	0.304	0.315	0.317
14	**8**	**1.5**	0.282	0.29	0.298	0.305	0.315	0.317
15	**10**	**1.5**	0.283	0.29	0.296	0.302	0.311	0.315
16	**2**	**2**	0.282	0.291	0.295	0.303	0.314	0.317
17	**4**	**2**	0.282	0.291	0.295	0.303	0.312	0.315
18	**6**	**2**	0.283	0.291	0.296	0.302	0.311	0.315
19	**8**	**2**	0.283	0.291	0.296	0.301	0.311	0.315
20	**10**	**2**	0.283	0.291	0.296	0.301	0.311	0.34

21	**2**	**2.5**	0.284	0.291	0.295	0.302	0.311	0.315
22	**4**	**2.5**	0.284	0.291	0.296	0.301	0.309	0.312
23	**6**	**2.5**	0.284	0.291	0.296	0.301	0.309	0.312
24	**8**	**2.5**	0.284	0.291	0.296	0.301	0.309	0.302
25	**10**	**2.5**	0.284	0.291	0.296	0.301	0.309	0.302

Table No.4 Changes in Optical Density of jaggery sample during storage

Ash Content

The ash content slightly increased from initial 0 week up to 15 week. The ash content of jaggery samples after 15 week of storage was in the range of minimum 0.96 to a maximum of 1.06 (control). This might be due to relatively more increase in mineral salts in uncoated sample than other samples. This could be the reason that edible coating may helped in prevention of more ash formation thereby having comparatively less ash content and increasing the shelf life of jaggery samples. After 12 weeks of storage it was observed factor WPC had a significant effect on ash content at 1% level of significance while CMC had a significant effect at 5% level of significance. Also it was observed that the influence of their interactions had non-significant effect on ash content as calculated F values (F_{cal}) are more than tabulated F values (F_{tab}) for both 1% and 5 % level of significance.

			Ash content (%)					
Treatments	**WPC (%)**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	**0**	**0**	0.96	0.96	0.96	0.96	0.96	1.06
1	**2**	**0.5**	0.97	0.97	0.97	0.97	0.97	0.97
2	**4**	**0.5**	0.97	0.97	0.97	0.97	0.97	0.97
3	**6**	**0.5**	0.97	0.97	0.97	0.97	0.97	0.97
4	**8**	**0.5**	0.97	0.97	0.97	0.97	0.97	0.97
5	**10**	**0.5**	0.97	0.97	0.97	0.97	0.97	0.97
6	**2**	**1**	0.96	0.96	0.96	0.96	0.96	0.96
7	**4**	**1**	0.97	0.97	0.97	0.97	0.97	0.97
8	**6**	**1**	0.97	0.97	0.97	0.97	0.97	0.97
9	**8**	**1**	0.97	0.97	0.97	0.97	0.97	0.97
10	**10**	**1**	0.97	0.97	0.97	0.97	0.97	0.97
11	**2**	**1.5**	0.97	0.97	0.97	0.97	0.97	0.97
12	**4**	**1.5**	0.96	0.96	0.96	0.96	0.96	0.96
13	**6**	**1.5**	0.97	0.97	0.97	0.97	0.97	0.97
14	**8**	**1.5**	0.97	0.97	0.97	0.97	0.97	0.97
15	**10**	**1.5**	0.97	0.97	0.97	0.97	0.98	0.98
16	**2**	**2**	0.97	0.97	0.97	0.97	0.97	0.97
17	**4**	**2**	0.97	0.97	0.97	0.97	0.97	0.97
18	**6**	**2**	0.97	0.97	0.97	0.97	0.97	0.97
19	**8**	**2**	0.97	0.97	0.97	0.97	0.98	0.99
20	**10**	**2**	0.98	0.98	0.98	0.99	0.99	0.99
21	**2**	**2.5**	0.97	0.97	0.97	0.97	0.98	0.98
22	**4**	**2.5**	0.97	0.97	0.97	0.97	0.98	0.98
23	**6**	**2.5**	0.97	0.97	0.97	0.97	0.98	0.98
24	**8**	**2.5**	0.98	0.98	0.98	0.99	1.01	1.01
25	**10**	**2.5**	0.98	0.98	0.98	0.99	1.01	1.01

Table No.5 Changes in Ash content of jaggery samples during storage

Total Viable Count

The initial TVC (total viable count) in terms of colony forming unit (Cfu g^{-1}) in the treatment was 2.16 x 10^3 to 2.32 x 10^3. It was observed from the storage study that total viable count followed increasing trend from initial 0 week to 15 week of storage period. **Narain and Singh (1963)** reported that microbiological deterioration is one of the major problem associated with jaggery storage. He also stated that moisture absorption during storage may aggravate the problem of microbial spoilage. **Khanna and Chakarvarti (2009)** observed that highly humid condition prevailing during storage leads to microbial spoilage of jaggery. At the end of storage weeks the maximum colonies were found 7.6 x 10^3 (Control) and minimum colonies were 5.20 x 10^3 (Treatments 20, 24 & 25). This show that coating of jaggery sample with WPC & CMC may help to reduce the deterioration of jaggery sample by microorganism up to some extent. The ANOVA of total viable count in jaggery samples upto 15 weeks of storage shows that the factor WPC and CMC had a significant effect as calculated F value (F_{cal}) is more than tabulated F value (F_{tab}) at 1 % level of significant. Effect of WPC was found to be more pronounced on total viable count than effect of CMC. Also it was observed that the influence of their interactions had significant effect on total viable count as calculated F values (F_{cal}) are more than tabulated F values (F_{tab}) for 1% level of significance.

			TVC (Cfu g^{-1})					
Treatments	**WPC (%)**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	**0**	**0**	2.16×10^3	3.04×10^3	4.0×10^3	5.20×10^3	6.60×10^3	7.6×10^3
1	**2**	**0.5**	2.16×10^3	3.04×10^3	4.0×10^3	5.20×10^3	6.56×10^3	7.6×10^3
2	**4**	**0.5**	2.16×10^3	2.92×10^3	3.60×10^3	5.0×10^3	6.44×10^3	7.2×10^3
3	**6**	**0.5**	2.16×10^3	2.92×10^3	3.60×10^3	5.0×10^3	6.44×10^3	7.2×10^3
4	**8**	**0.5**	2.32×10^3	2.88×10^3	3.60×10^3	4.88×10^3	5.80×10^3	6.60×10^3
5	**10**	**0.5**	2.16×10^3	2.84×10^3	3.52×10^3	4.80×10^3	5.80×10^3	6.60×10^3
6	**2**	**1**	2.16×10^3	2.88×10^3	3.52×10^3	4.84×10^3	5.80×10^3	6.60×10^3
7	**4**	**1**	2.16×10^3	2.88×10^3	3.52×10^3	4.84×10^3	5.80×10^3	6.60×10^3
8	**6**	**1**	2.16×10^3	2.88×10^3	3.52×10^3	4.84×10^3	5.80×10^3	6.60×10^3
9	**8**	**1**	2.16×10^3	2.84×10^3	3.52×10^3	4.48×10^3	5.52×10^3	6.56×10^3
10	**10**	**1**	2.32×10^3	2.60×10^3	3.0×10^3	4.20×10^3	4.88×10^3	5.80×10^3
11	**2**	**1.5**	2.16×10^3	2.60×10^3	3.0×10^3	4.40×10^3	5.28×10^3	6.44×10^3
12	**4**	**1.5**	2.16×10^3	2.60×10^3	3.0×10^3	4.40×10^3	5.28×10^3	6.44×10^3
13	**6**	**1.5**	2.16×10^3	2.60×10^3	3.0×10^3	4.20×10^3	4.88×10^3	5.28×10^3
14	**8**	**1.5**	2.32×10^3	2.56×10^3	3.0×10^3	4.0×10^3	4.88×10^3	5.28×10^3
15	**10**	**1.5**	2.32×10^3	2.56×10^3	3.0×10^3	4.0×10^3	4.84×10^3	5.28×10^3
16	**2**	**2**	2.16×10^3	2.56×10^3	3.0×10^3	4.20×10^3	4.84×10^3	5.28×10^3
17	**4**	**2**	2.16×10^3	2.56×10^3	3.0×10^3	4.0×10^3	4.88×10^3	5.28×10^3
18	**6**	**2**	2.16×10^3	2.56×10^3	3.0×10^3	4.0×10^3	4.88×10^3	5.28×10^3
19	**8**	**2**	2.32×10^3	2.48×10^3	2.92×10^3	3.56×10^3	4.24×10^3	5.52×10^3
20	**10**	**2**	2.32×10^3	2.48×10^3	2.88×10^3	3.52×10^3	4.20×10^3	5.2×10^3
21	**2**	**2.5**	2.32×10^3	2.48×10^3	2.92×10^3	3.60×10^3	4.24×10^3	5.60×10^3
22	**4**	**2.5**	2.32×10^3	2.56×10^3	2.92×10^3	3.56×10^3	4.24×10^3	5.80×10^3
23	**6**	**2.5**	2.32×10^3	2.56×10^3	2.92×10^3	3.56×10^3	4.24×10^3	5.80×10^3
24	**8**	**2.5**	2.36×10^3	2.48×10^3	2.88×10^3	3.52×10^3	4.20×10^3	5.2×10^3
25	**10**	**2.5**	2.36×10^3	2.48×10^3	2.88×10^3	3.52×10^3	4.20×10^3	5.2×10^3

Table No. 6 Changes in TVC of jaggery samples during storage

Mold Count/ Yeast Count

The initial yeast/ mold count of jaggery samples in terms of colony forming unit (Cfu g^{-1}) in treatments was 3.6 x 10^2. It was observed from the storage study that yeast/mold count followed increasing trend from initial 0 week to 15 week of storage in all treatment. **Javelekar *et al.* (1979)** found faster deterioration of jaggery due to fungus development during rainy season. **Kunte (1952)** correlated moisture absorption with growth of microorganism on the stored jaggery blocks start running off during rainy season due to high fungal growth in the blocks. At the end of storage weeks the maximum colonies were found 8.8 x 10^2 (Control) and minimum colonies were 7.20 x 10^2 (Treatment 9, 10, 14, 15, 18 & 19). This show that coating of jaggery sample with WPC & CMC may help to reduce the deterioration of jaggery sample by microorganism up to some extent. The ANOVA of yeast/mold count in jaggery samples upto 15 weeks of storage shows that the factor WPC and CMC had a significant effect as calculated F value (F_{cal}) is more than tabulated F value (F_{tab}) at 1 % level of significant. Effect of WPC was found to be more pronounced on yeast/mold count than effect of CMC. Also it was observed that the influence of their interactions had significant effect on yeast/mold count as calculated F values (F_{cal}) are more than tabulated F values (F_{tab}) for 1% level of significance.

			Mould count (Cfu g^{-1})					
Treatments	**WPC (%)**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	**0**	**0**	3.60×10^2	4.8×10^2	5.60×10^2	6.40×10^2	7.20×10^2	8.8×10^2
1	**2**	**0.5**	3.60×10^2	4.8×10^2	5.60×10^2	6.40×10^2	7.20×10^2	8.8×10^2
2	**4**	**0.5**	3.60×10^2	4.8×10^2	5.20×10^2	6.0×10^2	6.80×10^2	8.4×10^2
3	**6**	**0.5**	3.60×10^2	4.8×10^2	5.20×10^2	6.0×10^2	6.80×10^2	8.4×10^2
4	**8**	**0.5**	3.60×10^2	4.8×10^2	5.20×10^2	6.0×10^2	6.80×10^2	8.4×10^2
5	**10**	**0.5**	3.60×10^2	4.40×10^2	5.60×10^2	6.0×10^2	6.80×10^2	8.4×10^2
6	**2**	**1**	3.60×10^2	4.40×10^2	4.8×10^2	6.0×10^2	6.80×10^2	8.4×10^2
7	**4**	**1**	3.60×10^2	4.40×10^2	4.8×10^2	6.0×10^2	6.80×10^2	8.0×10^2
8	**6**	**1**	3.60×10^2	4.40×10^2	4.8×10^2	6.0×10^2	6.80×10^2	8.0×10^2
9	**8**	**1**	3.60×10^2	4.40×10^2	4.8×10^2	5.60×10^2	6.0×10^2	7.20×10^2
10	**10**	**1**	3.60×10^2	4.40×10^2	4.8×10^2	5.60×10^2	6.0×10^2	7.20×10^2
11	**2**	**1.5**	3.60×10^2	4.40×10^2	4.8×10^2	6.0×10^2	6.80×10^2	8.0×10^2
12	**4**	**1.5**	3.60×10^2	4.40×10^2	4.8×10^2	6.0×10^2	6.80×10^2	8.0×10^2
13	**6**	**1.5**	3.60×10^2	4.40×10^2	4.8×10^2	6.0×10^2	6.80×10^2	8.0×10^2
14	**8**	**1.5**	3.60×10^2	4.40×10^2	4.8×10^2	5.60×10^2	6.0×10^2	7.20×10^2
15	**10**	**1.5**	3.60×10^2	4.40×10^2	4.8×10^2	5.60×10^2	6.0×10^2	7.20×10^2
16	**2**	**2**	3.60×10^2	4.40×10^2	4.8×10^2	6.0×10^2	6.80×10^2	8.0×10^2
17	**4**	**2**	3.60×10^2	4.40×10^2	4.8×10^2	6.0×10^2	6.80×10^2	8.0×10^2
18	**6**	**2**	3.60×10^2	4.0×10^2	4.40×10^2	5.60×10^2	6.0×10^2	7.20×10^2
19	**8**	**2**	3.20×10^2	4.0×10^2	4.40×10^2	5.60×10^2	6.0×10^2	7.20×10^2
20	**10**	**2**	3.20×10^2	4.0×10^2	4.40×10^2	6.40×10^2	7.20×10^2	7.6×10^2
21	**2**	**2.5**	3.20×10^2	4.0×10^2	4.40×10^2	6.0×10^2	6.80×10^2	7.8×10^2
22	**4**	**2.5**	3.60×10^2	4.0×10^2	4.40×10^2	6.0×10^2	6.80×10^2	7.8×10^2
23	**6**	**2.5**	3.20×10^2	4.0×10^2	4.40×10^2	6.40×10^2	7.20×10^2	7.6×10^2
24	**8**	**2.5**	3.20×10^2	4.0×10^2	4.40×10^2	6.40×10^2	7.20×10^2	7.6×10^2
25	**10**	**2.5**	3.20×10^2	4.0×10^2	4.40×10^2	6.40×10^2	7.20×10^2	7.6×10^2

Table No. 7 Changes in Mould/Yeast count of jaggery samples during storage

Hardness

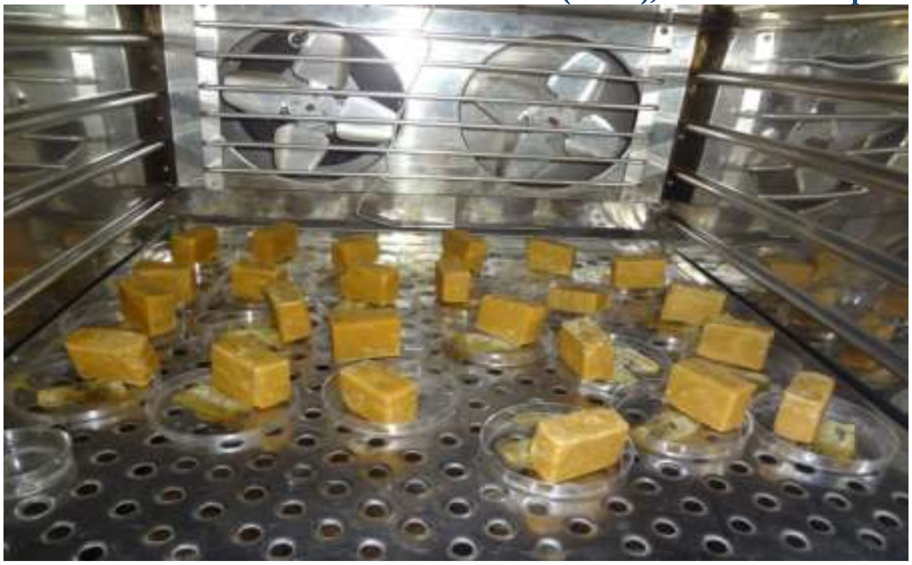
The initial hardness in terms of force required in Newton (N) to compress the sample completely was in the range of 11.08 to 11.12 in all the treatment. It was observed from the storage study that hardness followed an increasing trend from initial 0 week to 12th week of storage period. Upto 12^{th} week there were increases in hardness found in all the jaggery samples. Maximum hardness was found in control (38.2). This can be observed that coating of jaggery samples could have helped in retaining the desirable moisture up to an extent for soft texture while in control lead to an excessive moisture loss from leading to undesirable dry, brittle and hard texture. After 15^{th} week of storage there was difference in hardness found as compared to initial 12 week due to increase in humidity. In control hardness was reduced to 28.2 from 38.2and in another treatment there were slight decrease in hardness as compared with hardness found in 12 week. This can be observed coating of jaggery samples could help upto some extent in retaining the texture of jaggery. The ANOVA of hardness in jaggery samples upto 15 weeks of storage shows that the factor WPC and CMC had a significant effect as calculated F value (F_{cal}) is more than tabulated F value (F_{tab}) at 1 % level of significant.

			Hardness (Newton)					
Treatments	**WPC (%)**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	**0**	**0**	11.12	14.08	27.86	37.6	38.2	28.2
1	**2**	**0.5**	11.12	14.08	27.86	37.6	38.2	30.2
2	**4**	**0.5**	11.12	14.04	27.86	37.6	38.2	30.2
3	**6**	**0.5**	11.12	14.04	27.86	37.6	38.22	30.2
4	**8**	**0.5**	11.12	14.04	27.86	37.6	38.22	30.2
5	**10**	**0.5**	11.12	13.94	26.86	32.87	28.2	26.22
6	**2**	**1**	11.12	13.94	26.86	34.45	28.2	26.22
7	**4**	**1**	11.12	14.08	27.86	34.45	24.45	24.45
8	**6**	**1**	11.12	14.08	27.86	34.45	34.45	32.4
9	**8**	**1**	11.09	14.08	27.86	34.45	34.45	32.4
10	**10**	**1**	11.08	13.94	26.86	27.86	28.45	28.45
11	**2**	**1.5**	11.12	13.94	26.86	32.2	32.4	32.4
12	**4**	**1.5**	11.12	13.94	26.86	32.2	32.4	32
13	**6**	**1.5**	11.12	15.78	27.76	32.2	32.4	32
14	**8**	**1.5**	11.12	15.78	27.76	32.2	32.4	32.45
15	**10**	**1.5**	11.12	16.85	27.76	33.03	33.03	32.45
16	**2**	**2**	11.12	15.78	29.86	38.86	39.13	38.86
17	**4**	**2**	11.12	16.85	29.86	38.86	39.13	38.86
18	**6**	**2**	11.12	16.87	29.86	38.86	39.86	39.13
19	**8**	**2**	11.12	18.05	29.86	38.86	39.86	39.13
20	**10**	**2**	11.12	18.4	30.22	38.86	39.86	28.4
21	**2**	**2.5**	11.12	18.05	30.22	38.86	39.86	28.89
22	**4**	**2.5**	11.12	18.05	27.34	32.87	33.4	28.24
23	**6**	**2.5**	11.12	18.4	27.34	32.87	33.4	28.2
24	**8**	**2.5**	11.08	18.4	27.34	32.87	33.03	28.76
25	**10**	**2.5**	11.08	18.4	27.34	32.87	33.03	28.76

Table No. 8 Changes in Hardness of jaggery samples during storage

Sensory characteristics of jaggery samples

The sensory evaluation was done for liking of jaggery samples on the basis of color, taste, flavor, texture, aroma and appearance and Overall Acceptability Score (OAA) was calculated. A panel of 10 sensory panelists drawn from amongst the students and staff of various departments were selected to evaluate the samples using 9-point Hedonic Scale. The sensory characteristics color, appearance, flavor, texture, taste and overall acceptability of jaggery samples were recorded, which are mentioned in percent **(Annexure II, III & IV).**



Edible coated jaggery

Annexure-I

Week (Date)	Temperature (˚C)	Humidity (%)
0 week (6/03/13)	23.5	60
1st week (13/03/13)	24.5	62
2nd week (20/03/13)	27.5	54
3rd week (27/03/13)	24	50
4th week (3/03/13)	25	44
5th week (10/04/13)	29.5	40
6th week (17/04/13)	30	42
7th week (24/04/13)	31	38
8th week (1/05/13)	33	39
9th week (8/05/13)	30	38
10th week (15/05/13)	31.6	36
11th week (22/05/13)	37.5	28
12th week (27/05/13)	33.5	30
13th week (3/06/13)	32.7	58
14th week (10/06/13)	30.1	88
15th week (17/06/13)	26	93

Annexure –II Sensory Evaluation (Changes in Appearance of jaggery samples during storage)

Treatments	WPC (%)	CMC (%)	0 week	3 week	6 week	9 week	12 week	15 week
Control	**0**	**0**	8	8	8	7.5	7.5	7
1	**2**	**0.5**	8	8	8	7.5	7.5	7
2	**4**	**0.5**	8	8	8	7.5	7.5	7
3	**6**	**0.5**	8	8	8	7.5	7.5	7
4	**8**	**0.5**	9	9	9	8	8	7.5
5	**10**	**0.5**	8.5	8.5	8.5	8	8	7.5

6	**2**	**1**	9	8.5	8.5	8	8	7.5
7	**4**	**1**	9	9	9	8	8	7.5
8	**6**	**1**	8	8	8	7.5	7.5	7
9	**8**	**1**	8	8	8	7.5	7.5	7
10	**10**	**1**	8	8	8	7.5	7.5	7
11	**2**	**1.5**	7.5	7.5	7.5	7	7	6.5
12	**4**	**1.5**	7.5	7.5	7.5	7	7	6.5
13	**6**	**1.5**	8	8	8	7.5	7.5	7
14	**8**	**1.5**	8	8	8	7.5	7.5	7
15	**10**	**1.5**	8	8	8	7.5	7.5	7
16	**2**	**2**	9	8.5	8.5	7.5	7.5	7
17	**4**	**2**	7.5	7.5	7.5	7.5	7.5	7
18	**6**	**2**	7.5	7.5	7.5	7.5	7.5	7
19	**8**	**2**	7.5	7.5	7.5	7	7	6.5
20	**10**	**2**	8	8	8	7.5	7.5	7
21	**2**	**2.5**	8	8	8	7.5	7.5	7
22	**4**	**2.5**	8	8	8	7.5	7.5	7
23	**6**	**2.5**	8	8	8	7.5	7.5	7
24	**8**	**2.5**	8	8	8	7.5	7.5	7
25	**10**	**2.5**	8	8	8	7.5	7.5	7

Annexure –III Sensory Evaluation (Changes in Taste of jaggery samples during storage)

Treatments	**WPC (%)**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	**0**	**0**	9	8	8	8	8	8
1	**2**	**0.5**	9	8	8	8	8	8
2	**4**	**0.5**	9	8	8	8	8	8
3	**6**	**0.5**	8	8	8	8	8	8
4	**8**	**0.5**	9	9	9	8	8	7.5
5	**10**	**0.5**	8.5	8.5	8.5	8	8	7.5
6	**2**	**1**	9	8.5	8.5	8	8	7.5
7	**4**	**1**	9	9	9	8	8	7.5
8	**6**	**1**	8	8	8	7.5	7.5	7
9	**8**	**1**	8	8	8	7.5	7.5	7
10	**10**	**1**	8	8	8	7.5	7.5	7
11	**2**	**1.5**	9	8	8	7	7	6.5
12	**4**	**1.5**	9	8	8	7	7	6.5
13	**6**	**1.5**	9	8	8	7.5	7.5	7
14	**8**	**1.5**	8	8	8	7.5	7.5	7
15	**10**	**1.5**	8	8	8	7.5	7.5	7
16	**2**	**2**	9	8.5	8.5	7.5	7.5	7
17	**4**	**2**	9	8	8	7.5	7.5	7
18	**6**	**2**	9	8	8	7.5	7.5	7
19	**8**	**2**	8	8	8	7	7	6.5
20	**10**	**2**	8	8	8	7.5	7.5	5
21	**2**	**2.5**	8	8	8	7.5	7.5	7
22	**4**	**2.5**	8	8	8	7.5	7.5	7

23	**6**	**2.5**	8	8	8	7.5	7.5	7
24	**8**	**2.5**	8	8	8	7.5	7.5	5
25	**10**	**2.5**	8	8	8	7.5	7.5	5

Annexure –IV Sensory Evaluation (Changes in Overall acceptability of jaggery samples during storage)

Treatments	**WPC (%**	**CMC (%)**	**0 week**	**3 week**	**6 week**	**9 week**	**12 week**	**15 week**
Control	**0**	**0**	9	8	8	8	8	8
1	**2**	**0.5**	9	8	8	8	8	8
2	**4**	**0.5**	9	8	8	8	8	8
3	**6**	**0.5**	8	8	8	8	8	8
4	**8**	**0.5**	9	9	9	8	8	7.5
5	**10**	**0.5**	8.5	8.5	8.5	8	8	7.5
6	**2**	**1**	8	8.5	8.5	8	8	7.5
7	**4**	**1**	8	8	8	8	8	7.5
8	**6**	**1**	8	7.5	7.5	7.5	7.5	7
9	**8**	**1**	8	7.5	7.5	7.5	7.5	7
10	**10**	**1**	8	7.5	7.5	7.5	7.5	7
11	**2**	**1.5**	8	7.5	7.5	7	7	6.5
12	**4**	**1.5**	8	8	8	7	7	6.5
13	**6**	**1.5**	8	8	8	7.5	7.5	7
14	**8**	**1.5**	8	8	8	7.5	7.5	7
15	**10**	**1.5**	8	7.5	7.5	7.5	7.5	7
16	**2**	**2**	8	7.5	7.5	7.5	7.5	7
17	**4**	**2**	8	7.5	7.5	7.5	7.5	7
18	**6**	**2**	8	7.5	7.5	7.5	7.5	7
19	**8**	**2**	8	7.5	7.5	7	7	7
20	**10**	**2**	8	7.5	7.5	7.5	7.5	5
21	**2**	**2.5**	8	7.5	7.5	7.5	7.5	7
22	**4**	**2.5**	8	7.5	7.5	7.5	7.5	7
23	**6**	**2.5**	8	7.5	7.5	7.5	7.5	7
24	**8**	**2.5**	8	7.5	7.5	7.5	7.5	5
25	**10**	**2.5**	8	7.5	7.5	7.5	7.5	5

CONCLUSION

The majority of the sugarcane growers are manufacturing jaggery with minimum capital investment which provides jobs to the unemployed rural people. The jaggery manufacturers are mostly small and marginal farmers relying on quick returns from jaggery. It is, therefore, essential to safeguard the sugarcane growers to earn more profit from their jaggery manufacturing unit by improving its qualities through. Jaggery storage is always a big problem during the summer and rainy seasons. The development of new edible coating with improved functionality and performance applied on jaggery found best with other quality parameters research should be conducted to develop edible coating with different chemical composition to understand the mechanism of the effect of coatings on preserving the quality of jaggery, in order to develop methods for handling and storage of jaggery without loss of quality.

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