2013 International Conference on Food and Agricultural Sciences
IPCBEE vol.55 (2013) © (2013) IACSIT Press, Singapore
DOI: 10.7763/IPCBEE. 2013. V55. 11

Microbial, Physicochemical and Shelf-life Evaluation of Muscovado in Different Packaging Materials at Various Storage Time

Karen Luz Y. Teves [1+], Erlinda I. Dizon [2], Jovita L. Movillon [3], and Aldwin M. Teves [4]

[1]Assistant Professor, Central Philippines State University, Kabankalan City, Negros Occidental
[2]Professor, Institute of Food Science and Technology, University of the Philippines, Los Bańos, Laguna

[3]Professor, Dept. of Chemical Engineering, University of the Philippines Los Bańos, Laguna

[4]Associate Professor, Central Philippines State University, Kabankalan City, Negros Occidental

Abstract. Muscovado is a nutritious sugar that is brown in color, has coarser, stickier texture, distinct taste and aroma making it unique and highly prized. Quality evaluation of muscovado stored in various packaging materials was done on different storage time. The evaluation involved microbial and physicochemical property determination of muscovado stored in six types of packaging materials; Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE) plastics, plastic and glass containers, aluminum pouch and open storage (control). Stored muscovado at ambient temperature were analyzed periodically at 21, 42, 53 and 84 days for Standard Plate Count (SPC), mold and yeast counts, moisture content (MC), water activity (aw), safety factor (SF), sucrose, reducing sugar and color. SPC, mold and yeast counts steadily increased at 21 days after processing until 42nd day and slowly declined until the 84th day. Of the physicochemical properties, only sucrose content of muscovado decreased with storage time. MC, aw and SF increased with storage time. Results showed that glass container, aluminum pouch and HDPE plastic are appropriate muscovado packaging materials. Glass container produced the most stable muscovado, but is impractical to use, thus a flexible packaging material with combined properties of aluminum pouch and HDPE plastic is recommended.

Keywords: Shelf-life, muscovado, packaging material, microbial, storage time

1. Introduction

Muscovado is a non-centrifugal sugar commonly called *gur*, *jaggery, khandsari* in South Asia, *panela, dulce* in Latin America, *desi* in Pakistan, *khandasari* in India, *chancaca* in Colombia, *demirara, turbinado* in the Carribean and Central America, black sugar in Japan and Taiwan [1]. It is sticky and brown in color and is considered a specialty sugar because of its inherent taste and aroma due to high molasses content. Muscovado, gur or jaggery is one of the ancient sweetening agents known to man and is an integral part of the rural diet in many countries [2]. Muscovado is made from sugarcane juice simply by evaporation. Muscovado, being a low cost, traditional, eco-friendly and nutritive sweetener, offers a viable alternative to sucrose [3]. It may look less attractive than crystal white sugar but it is a healthier food. Composition and storage conditions of muscovado (both physical and chemical) are important factors that determine the keeping quality of product. During storage, muscovado basically suffers from different types of deterioration: physical, chemical, biological and microbiological [4]. Storage problems include running-off (liquefaction) and color deterioration [3]. These problems are due to absorption of moisture and microbial attack. Selection of packaging material for muscovado depends not only on its technical suitability but also on the availability and cost in a particular area [5]. In the market, muscovado are packed in polyethylene plastic of any density,

[+] Corresponding author. Tel.: +639158682519.
E-mail address: kartevs@yahoo.ca.

plastic container or glass jar with cover and stored at ambient room temperature [6]. No standardized method of storage is followed for preserving muscovado in market places [7]. In some rural areas, muscovado is displayed in native baskets or mats [7]. To extend product shelf life, there should be selection of appropriate packaging material to ensure protection against contamination and moisture gain during transport and storage of muscovado. Because muscovado is a minimally processed food, its shelf life is poor and needs specific conditions [8]. The shelf life study of muscovado packed in specific packaging material is critical because it determines the packaging material that effectively prolongs shelf life of the product. Moreover, the study on storage behaviour of muscovado packed in various packaging materials may provide information on what factors affect rapid deterioration of the product and in the end, develop appropriate condition for its proper storage. This study aimed to evaluate the microbial, physicochemical and shelf life of muscovado sugar under various packaging materials and storage time.

2. Materials and Methods

2.1. Muscovado Sample Preparation

Matured (12-month old) VMC 86-550 sugarcane variety was used in processing muscovado. About 300 kg sugarcane was processed into muscovado by first crushing the juice using a three roller press mill following the procedure developed by ITDI-DOST [9]. Juice was filtered using a cheesecloth and preheated to 70 ^{0}C for 5 min. Preheated juice was limed at 1000 ppm until pH 7-7.5. Limed juice was allowed to settle for 2 hr, slowly decanted and filtered with cheesecloth. Filtered juice was boiled at 100-124^{0}C for 120-150 min until a massecuite is formed. The massecuite was transferred to a wooden tub and vigorously mixed until sugar clumps are formed. Muscovado was allowed to cool prior to weighing and packaging.

2.2. Packaging of Muscovado

Processed muscovado was divided into six equal portions. Each portion was packaged at 250 g per packaging material and designated various treatments as:

- T0 : Open storage /control treatment (muscovado placed in native basket)
- T1: Muscovado packed in Low Density Polyethylene plastic (LDP – 100 microns)
- T2: Muscovado packed in High Density Polyethylene plastic (HDP – 350 microns)
- T3: Muscovado packed in glass jar with cover
- T4: Muscovado packed in plastic container with cover
- T5: Muscovado packed in aluminum pouch, sealed

All samples were kept at ambient room temperature with mean temperature and relative humidity of 26.6 ^{o}C and 81%, respectively for a period of 12 weeks. All treatments were done in triplicate. Microbiological and physicochemical were carried out at an interval of three weeks during the entire storage period.

2.3. Physicochemical Analysis of Stored Muscovado

All stored muscovado samples were subjected to analysis after 21, 42, 53 and 84 days for mc using Ohaus MB25 moisture analyser, aw using a Thermoconstanter Novasina Model, sucrose, reducing sugar (RS), SF and color according to the standard methods described by the International Commission for Uniform Methods of Sugar Analysis (ICUMSA) [10]. To determine sucrose and RS, the Walker's Inversion method and Lane Eynon Constant Volume Method was used, respectively. ICUMSA color of muscovado was determined using the uv-vis spectrophotometer at absorbance 420 and 720 nm.

2.4. Microbiological Analysis of Stored Muscovado

Microbiological analysis of muscovado samples were done simultaneously with physicochemical analysis every three weeks for Standard Plate Count, Yeast and Mould count following the standard procedure in the Compendium of Methods for the Microbiological Examination of Foods [11].

2.5. Statistical Analysis

All obtained data were analysed using One-Way Analysis of Variance (ANOVA) per storage time at 5% level of significance with the aid of statistical software. If mean values were found significant, the data were further analysed using the Waller-Duncan Range Test to locate which sample is significantly different.

3. Results and Discussion

3.1. Microbial Properties of Stored Muscovado

Results presented in Table 2 indicated decrease in SPC of muscovado stored in all packaging materials based on initial population of $3.7x10^7$ (Table 1). Mold and yeast in muscovado stored in all types of packaging materials started to develop after 21 days, increased continuously until 42 days yet growth declined starting the 63rd day of storage. Muscovado sugar is hygroscopic in nature, and if stored in packaging, moisture uptake is minimal, thus microorganisms will not survive after long storage [12]. Muscovado in open storage (control) showed obvious signs of spoilage after 6th week of storage, thus, microbial counts were discontinued. This indicates that for safe consumption of muscovado, it should be stored in close container after processing [13]. There was no significant difference of SPC, mold and yeast counts of muscovado stored in all types of packaging materials in the entire storage time.

Table 1: Mean[1] Microbial and Physicochemical Properties of Muscovado after Processing

Parameter	Mean	Standard Error
Standard Plate Count	$3.7x10^7$	88334.59
Mold Count	0.00	0.00
Yeast Count	0.00	0.00
Moisture (%)	2.00	0.13
Water activity	0.33	0.02
Reducing sugar (%)	4.28	0.29
Sucrose (%)	80.77	2.48
Safety Factor	0.20	0.03
Color (I.U.)	12083.33	29.08

[1]N=3

Table 2: Mean[1] Values of Microbial Properties of Muscovado Packed in Various Packaging Materials

Microbial Count (CFU/g)	Treatment/ Packaging Material	Storage Time (Days)			
		21	42	63	84
Standard Plate Count	T0 (Control – Native basket)	$2.4x10^5$b	ND	ND	ND
	T1 (Low Density PE plastic)	$1.5x10^4$a	100.00	155.00	10.00
	T2 (High Density PE plastic)	$4x10^4$a	100.00	203.00	10.00
	T3 (Glass container)	$1x10^4$a	55.00	150.00	15.00
	T4 (Plastic container)	$2.5x10^4$a	57.00	150.50	10.00
	T5 (Aluminum pouch)	$6x10^4$a	150.00	202.00	10.00
Mold Count	T0 (Control – Native basket)	1486.58b	ND	ND	ND
	T1 (Low Density PE plastic)	15.00a	2.50	15.00	0.00
	T2 (High Density PE plastic)	7.50a	15.00	15.00	0.00
	T3 (Glass container)	9.76a	0.00	15.00	0.00
	T4 (Plastic container)	11.67a	15.00	2.50	0.00
	T5 (Aluminum pouch)	7.78a	13.75	15.00	0.00
Yeast Count	T0 (Control – Native basket)	486.58b	ND	ND	ND
	T1 (Low Density PE plastic)	5.00a	2.50	2.50	0.00
	T2 (High Density PE plastic)	486.58a	15.00	15.00	0.00
	T3 (Glass container)	15.00a	0.00	0.00	0.00
	T4 (Plastic container)	1486.58a	15.00	15.00	0.00
	T5 (Aluminum pouch)	15.00a	13.75	13.75	0.00

[1]N=3. Mean values with the same letter(s) in a column are not significantly different from each other at $P \leq 0.05$, ND – No data

3.2. Physicochemical Properties of Stored Muscovado

Except for sucrose content, all physicochemical properties of stored muscovado steadily increased after processing. From initial moisture of 2% (Table 1), muscovado stored in all types of packaging materials except plastic container increased until day 84. Muscovado stored in both plastic and glass containers had significantly lower mc than the rest of packaging materials (Table 3). This finding indicates that plastic and glass containers are good packaging materials to produce stable muscovado. Mc and aw are important determinants of shelf stability of a product [14]. SF is a ratio used to indicate the keeping quality of raw sugar. SF should not exceed 0.25; if SF exceeds 0.25 then sugar is prone to deterioration [13]. From an initial mc, Aw and SF of 2%, 0.33 and 0.20, respectively (Table 1), after 21 days, control muscovado significantly obtained the highest values compared to other packaging (SF=0.31). This indicates that muscovado will deteriorate if remained unpacked for a number of days. Aw is a measure of availability of water for biological reactions. Micro-organisms need water to survive and the higher the aw of food, the faster is the microbial growth [15]. It is assumed that if a food product contains high moisture, the product also have high water activity.

Table 3: Mean[1] Values of Physicochemical Properties of Muscovado Packed in Various Packaging Materials

Property	Treatment/ Packaging Material	Storage Time (Days)			
		21	42	63	84
Moisture content (%)	T0 (Control – Native basket)	4.00b	ND	ND	ND
	T1 (Low Density PE plastic)	3.00ab	4.67	4.22	4.11
	T2 (High Density PE plastic)	3.00ab	4.95	4.59	4.50
	T3 (Glass container)	2.67a	3.54	3.05	2.55
	T4 (Plastic container)	1.99a	4.44	1.95	3.56
	T5 (Aluminum pouch)	4.00b	4.95	4.78	4.93
Water activity	T0 (Control – Native basket)	0.32a	ND	ND	ND
	T1 (Low Density PE plastic)	0.37a	0.34	0.31	0.30
	T2 (High Density PE plastic)	0.36a	0.34	0.30	0.30
	T3 (Glass container)	0.67b	0.26	0.22	0.24
	T4 (Plastic container)	0.37a	0.32	0.17	0.27
	T5 (Aluminum pouch)	0.37a	0.32	0.30	0.30
Safety Factor	T0 (Control – Native basket)	0.35b	0.30c	0.31a	0.31a
	T1 (Low Density PE plastic)	0.19ab	0.25bc	0.35d	0.28d
	T2 (High Density PE plastic)	0.15ab	0.20ab	0.28c	0.24c
	T3 (Glass container)	0.15ab	0.18a	0.20b	0.20c
	T4 (Plastic container)	0.20ab	0.17a	0.37d	0.17b
	T5 (Aluminum pouch)	0.10a	0.23ab	0.26c	0.24c
Reducing sugar (%)	T0 (Control – Native basket)	6.06f	7.81f	9.01f	9.91
	T1 (Low Density PE plastic)	5.72e	7.47e	8.67e	9.37e
	T2 (High Density PE plastic)	4.66d	6.41d	7.61d	8.01d
	T3 (Glass container)	3.65a	5.40a	6.60a	6.60a
	T4 (Plastic container)	4.59c	6.34c	7.54c	7.84c
	T5 (Aluminum pouch)	4.54b	6.29b	7.49b	7.39b
Sucrose (%)	T0 (Control – Native basket)	78.57a	77.73a	76.09a	75.33a
	T1 (Low Density PE plastic)	79.68b	78.84b	77.30b	76.54b
	T2 (High Density PE plastic)	79.94b	79.10b	77.66b	76.90b
	T3 (Glass container)	81.11c	80.27c	79.33c	78.57c
	T4 (Plastic container)	79.87b	79.03b	77.69b	76.93b
	T5 (Aluminum pouch)	81.25c	80.41c	79.27c	78.51c
Color, I.U.	T0 (Control – Native basket)	13096.86e	13097.50e	13099.00e	13102.50e
	T1 (Low Density PE plastic)	13113.92f	13114.56f	13116.06f	13119.06f
	T2 (High Density PE plastic)	12580.29c	12580.93c	12582.43c	12582.93c
	T3 (Glass container)	12012.98b	12013.62b	12015.12b	12015.02b
	T4 (Plastic container)	12596.96d	12597.60d	12599.10d	12599.50d
	T5 (Aluminum pouch)	12001.53a	12002.17a	12003.67a	12003.27a

[1]N=3. Mean values with the same letter(s) in a column are not significantly different from each other at $P \leq 0.05$, ND – No data

Higher mc was observed in muscovado stored at control, LDPE plastic and plastic container (Table 3). Muscovado in glass container obtained low mc after 21, 42 and 84 days. Similar trend was observed in the aw, of which control muscovado and LDPE plastic had the highest Aw compared to other packaging. Aw of muscovado in plastic container declined after 63 days but increased steadily towards the 84th day of storage. Safety factor of control muscovado and LDPE plastic had higher SF compared to other packaging in all storage days except in the 63th storage day wherein muscovado in plastic container suddenly increased. Muscovado in aluminum pouch, glass container, HDPE plastic and plastic container obtained lower SF ranging from 0.1 to 0.37. Based on the results, mc, aw and SF have positive relationship, and increased with storage time (Fig. 1C). If mc of muscovado increases, Aw and SF also increase [16]. The longer the muscovado is stored, the more prone it is to deterioration if the packaging material used cannot prevent entrance of moisture from the environment [17]. RS in muscovado stored in all types of packaging increased with storage time.

Muscovado stored in glass container had significantly the lowest RS while control muscovado had significantly the highest RS from day 21 to 84. Sucrose content of muscovado stored in all types of packaging decreased with storage time. Muscovado stored in glass container and aluminum pouch had significantly the highest sucrose contents while control muscovado obtained significantly the lowest sucrose from storage day 21 to 84. Color of newly processed muscovado from 12083.33 I.U. (Table 1) increased with storage time in all types of packaging except in aluminum pouch and glass container. Muscovado stored in aluminum pouch and glass container had significantly lower color increase than with the rest of the packaging in the entire storage. Muscovado stored in LDPE plastic had significantly the highest increase in color from storage day 21-84.

Fig. 1 depicts the change in mc, aw and SF of muscovado stored in various packaging materials and storage time. From its initial mc, muscovado samples in all packaging increased rapidly after 42 days till the 84th day (Fig. 1A). Higher mc was observed in control muscovado, LDPE plastic and plastic container. Muscovado in glass container obtained low mc after 21, 42 and 84 days. Similar trend was observed in the aw, of which control muscovado and LDPE plastic had the highest aw compared to other packaging (Fig.1B). aw of muscovado in plastic container declined after 63 days but increased steadily towards the 84th day of storage. From its initial mc, muscovado in all packaging increased rapidly after 42 days till the 84th day (Fig. 1A).

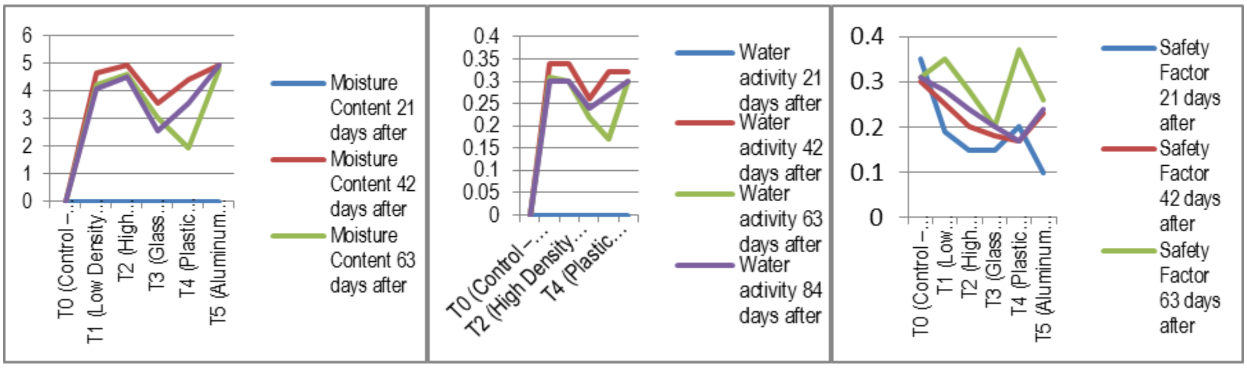

Fig 1: Moisture content (A), water activity (B) and Safety Factor (C) of muscovado at different storage time as a function of packaging materials

4. Conclusions

It can be inferred that as long as muscovado is stored in a close packaging material/container of any type, microorganisms cannot survive after 63 days. Moisture, aw and SF have positive relationship, and increase with storage time. The longer the muscovado is stored, the more prone it is to deterioration if the packaging material used cannot prevent entrance of moisture from the environment. Among physicochemical properties, only sucrose content of muscovado decreases with storage time. In an open storage, muscovado uptakes more moisture, increases its water activity, color and reducing sugar thereby lowering its sucrose content. The most appropriate packaging materials for muscovado are glass container, aluminum pouch and HDPE plastic based on the evaluated microbial and physicochemical across storage time.

5. Recommendation

Among the packaging materials, glass container produced the most stable muscovado in terms of physicochemical and shelf life, but it is impractical to use during product handling, marketing and transportation, thus it is recommended to develop a flexible packaging material for muscovado that has combined properties of aluminum pouch and HDPE plastic (350 microns).

6. Acknowledgement

The authors wish to express their sincere gratitude to the Philippine Department of Science and Technology – PCAARRD for funding this research.

7. References

[1] Philippine Development Assistance Program (PDAP). 2005. Prospects of the Muscovado Sugar Industry in the Philippines. Manila, Philippines.

[2] D. Mandal, S. Tudu, S. R. Mitra, G. C. De, “Effect of common packaging materials on keeping quality of sugarcane jaggery during monsoon season,” *Sugar Tech.*, 2006, **8** (2/3): 137-142.

[3] P. SHUKLA, 2012. Effect of edible coating and packaging on microbiological characteristics of jaggery. Prime Journal of Microbiology Research (PJMR)

[4] S. Uppal, “Storage of jaggery under low temperature for longer duration,” *Sugar Tech*, 2002, **4** (3-4): 177-178, 2002.

[5] Shinde, B. A., Marathe, D., Javalekar and S. Kadam. “Effect of form and colour of polythene-The wrapping material, on keeping quality of jaggery during storage,” *Indian Sugar*, 1983, **32** (12): 937-940.

[6] Patil, J.; H. Jadhav; R. Hasure; A. Hasabnis and J. Singh. Performance evaluation of gur moulding frame, IISR gur drying cum storage bin on keeping quality of jiggery. *Cooperative Sugar*, 1997, **28** (10): 759-760.

[7] P. V. Narayanan and M. Dordi. 1998, Indian Food Sector and Packaging–An overview. Modern Food Packaging, J. F. D Cunha, Indian Institute of Packaging, Mumbai.

[8] Uppal, S. and K. Sharma. “Evaluation of different methods of jaggery (gur) storage in sub-tropical region,” *Ind. J. Sugarcane Tech.*, 1998, **13** (9): 73-79, 1998.

[9] Industrial Technology Development Institute (ITDI-DOST). Guide Book on Improved Operating Practices in the Manufacture of Muscovado Sugar. Integrated Program on Cleaner Production Technologies-PCIERD-DOST.ISSN: 2251-127X, 2007, **2** (4): 121-125.

[10] Philippine Association of Sugar Technologists, Inc. (PHILSUTECH). 1997. Official Methods of Chemical Control for Philippine Cane Sugar Factories, Refineries and Distilleries.

[11] APHA. 2001. American Public Health Association (APHA) – Compendium of methods for the microbiological examination of foods. 3rd ed., Washington, D.C.

[12] Chand, K., A. Singh and M. Kulshrestha. Jaggery quality affected by hilly climatic conditions. *India Journal of Traditional Knowledge*. 2012, **11** (1): 172-176.

[13] New South Wales Food Authority. 2009. Shelf life-testing: “Use-by” dates for food safety. www.foodauthority.nsw.gov.au

[14] Saska, M. and V. Kochergin. Quality changes during storage of raw and VLC sugar: Effects of pH and Moisture. *International Sugar Journal 2009*, 2009, **111** (1324): 236-238.

[15] Compendium of Methods for the Microbiological Examination of Foods. 4th Edition. Edition, American Public Health Association.

[16] Teves, K. Y. 2012. Standardization of lime concentration and physicochemical characterization of muscovado sugar using different sugarcane varieties. Unpublished Ph.D. dissertation, UPLB, College, Laguna

[17] Kunte, M. 1952. Studies in the absorption of moisture by *gul* (jaggery) during storage. M.Sc. Thesis, University of Poona, Pune.