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PHYSICOCHEMICAL CHARACTERIZATION OF MUSCOVADO SUGAR USING DIFFERENT SUGARCANE VARIETIES AND STANDARDIZED LIME CONCENTRATION

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Abstract

Muscovado is a specialty sugar that has a distinct taste and aroma making it unique and highly prized. Standardization of lime concentration was done using ten SRA and VMC HYVs. Mixed juices and processed muscovado were analyzed for yield and physicochemical properties. Clarified juice produced from ten sugarcane varieties and two lime concentrations – 500 ppm (T1) and 1000 ppm (T2) were processed into muscovado sugar. Sugarcane variety caused a significant variation in the pol, MC, SF, RS, sucrose, color, insolubles and yield of muscovado sugars. MC of muscovado ranged from 1.45 -6.8%, ash-1.33 to 2.72%, RS -1.91 to 5.2%, sucrose- 77.9 to 92.97%, color - 8,122 to 39, 567 I. U. and insolubles- 0.2 to 1.26%. T2 muscovado of VMC 84-524 obtained the highest sugar yield of 11.1%. Findings showed that Phil 7464 is the right variety when using either 500 or 1000 ppm lime to obtain high pol muscovado. To process muscovado of lower MC and SF, Phil 99-0925 can be used at 500 ppm while Phil 7464 and VMC 87-95 at 1000 ppm. For low ash and high sucrose, at either 1000 or 500 ppm,

Phil 7464 is most ideal. At 500 ppm, Phil 99-0925, VMC 87-95 and Phil 7464 can be used. For low RS and insoluble, VMC 86-550, Phil 2001-0295 and Phil 99-1793 at 500 ppm can be utilized while 7464 and Phil 99-1793 at 1000 ppm. For high sucrose and sugar yield, Phil 99-0925, VMC 84-524 and VMC 86-550 at 500 ppm is appropriate and Phil 7464 at 1000 ppm. Either 500 or 1000 ppm lime concentration at specific varieties can be used to obtain quality muscovado. The six most suitable varieties to use for muscovado processing are; Phil 7464, VMC 84-524, VMC 86-550, VMC 87-95, Phil 99-0925 and Phil 2001-0295.

Keywords

Standardization, Lime Concentration, HYVs, Muscovado, Mixed Juice

1. Introduction

Muscovado is a non-centrifugal sugar that is brown in color, has coarser, stickier texture than most brown sugars and is used to be known as a “poor man’s sugar” (ITDI-DOST, 2007). It is now considered a specialty sugar because of its inherent taste and aroma due to high molasses content (PCARRD, 2006). In addition, its high molasses content makes it dark, strongly flavored, and very sticky making it unique, highly prized and in demand abroad (PDAP, 2005). Though muscovado production offers clear opportunities of poverty reduction and enhancing rural enterprises, the use of outdated equipment and machine hampers the efficiency of juice extraction and product quality (PDAP, 2005). Of the 258 muscovado mills in the country, 11 mills are still using extractors drawn by carabaos, 247 mills are motor-driven, and very few use upgraded technology developed by SRA (ITDI-DOST, 2007). Today, only two muscovado mills passed the strict global market requirements in the Philippines. Developed countries like Japan, Netherlands and Europe are willing to pay very high prices for quality muscovado. However, they have strict specific requirements in the sucrose content, color, moisture, pH, brix, sediment contents and other physicochemical properties (PDAP, 2005). These specific requirements could only be met by a well-equipped and upgraded mill that ordinary muscovado producers cannot compete with. Small-scale muscovado producers find it very expensive to upgrade their conventional mills (PDAP, 2005). These constraints are some of the reasons why small-scale muscovado producers hold on to traditional production. The process of juice clarification and evaporation in muscovado production is not yet fully established (ITDI-DOST, 2007).

In conventional muscovado plants, the amount of lime added is based on the smell or color of the juice (ITDI-DOST, 2007). Contamination and presence of sediments are one of the reasons why Philippine made muscovado are of low quality and fail to pass the foreign standards (Latiza, 2004). To date, there is very limited published information regarding the right sugarcane variety used in muscovado processing in the Philippines. In addition, muscovado sugar quality and recovery using different varieties have not been explored. The quality of juice and sugar depends largely on cane variety (PDAP, 2005).

Given these situations, juice clarification, the first and most important critical point in muscovado processing needs to be studied. Appropriate lime concentration should also be determined to identify the maximum amount of impurities to be removed. Determination of the suitable variety among recommended sugarcane cultivars and the exact amount of lime used in juice clarification might lower insoluble in the product. These activities may lead to increased muscovado recovery. Moreover, results of this study will enhance livelihood opportunities particularly the small resource sugarcane farmers to plant the suitable sugarcane variety and process muscovado on their own with the assurance of producing quality muscovado sugar. In the end, this study will benefit sugarcane farmers in areas where no sugar mills are present. This study aimed to standardize the lime concentration used in juice clarification for muscovado processing and determine the physicochemical properties of processed muscovado sugar using different sugarcane varieties. The sugarcane juice quality and muscovado sugar yield are also determined. Consequently, the study identified the suitable varieties at particular lime concentration to produce quality muscovado.

2. Materials and Methods

2.1 Standardization of Lime Concentration

The aim of clarification is to remove the maximum quantity of impurities in the mixed juice at the earliest stage. Juice clarification has a great impact on boiling house operations, sugar yield, and refining quality of raw sugar. The addition of lime during preheating of juice reduces the natural acidity of the cane juice, limiting the formation of invert sugars (Russel, 1998). Optimum clarification condition can be achieved between pH values of 8 and 9.5 (Hamerski, et al., 2009). To standardize the lime concentration needed to juice clarification and raise the

mixed juice pH to neutrality, five lime concentrations were used including a control (no lime added), 250 ppm w/w, 500 ppm w/w, 1000 ppm w/w and 1500 ppm w/w. A three-roller mill was used to crush the canes using 30% imbibition water and matured (12 months) VMC 87-95 sugarcane samples were used. Initial pH of mixed juice was determined per lime treatment. The mixed juice pH of the treatments ranged from 4.8-5.4. To obtain a uniform pH of mixed juice samples, initial pH of MJ was adjusted to pH 6.0 by gradual addition of a food grade lime. The standard lime concentration obtained was used in muscovado processing.

2.2 Sugarcane Samples

Ten HYVs and matured (12 months of age) sugarcane varieties were used in the study; five SRA (Sugar Regulatory Administration) and five VMC (Victorias Milling Corporation). The sugarcane samples were harvested from Kabankalan City, Bago City and La Carlota City, Negros Occidental, Philippines. The following varieties used in the study were: VMC 85-484, VMC 84-524, VMC 86-550, VMC 87-95 and VMC 84-549 as VMC varieties while SRA varieties included Phil 2001-0295, Phil 2000-2569, Phil 99-1793, Phil 99-0925 and Phil 7464.

2.3 Juice Extraction and Analysis

Juice extraction of ten sugarcane varieties used a three roller mill and 30% imbibition water along three mill passes. About 30 kg sugarcane per variety was milled. The First Expressed Juice (FEJ), Juice 2 (produced from 2nd mill pass) and Last Expressed Juice (LEJ) were combined to produce the Mixed Juice (MJ) samples. A little portion of the Mixed Juice (250 ml) was collected in a clean dry container and submitted for laboratory analysis to determine the degree brix and percent pol according to the standard methods followed by the International Commission for Uniform Methods of Sugar Analysis (ICUMSA) (PHILSUTECH, 1997). Juice analysis was replicated three times.

2.4 Muscovado Processing

The remaining mixed juice was used for processing muscovado. For each sugarcane variety, two lime treatments were used; 500 ppm (T1) and 1000 ppm (T2) in muscovado processing to a total of twenty treatment combinations (Table 2). In T1, MJ was filtered using cheese cloth and preheated to 70°C for 5 min. A food grade lime with a concentration of 500 ppm was added to the preheated MJ. Limed MJ was allowed to settle for 2 hr, slowly decanted and filtered with cheesecloth. Filtered MJ was boiled at 100-124⁰C for 120-150 min until a

massecuite is formed. The massecuite was transferred to a wooden tub and continuously mixed until muscovado sugar clumps formed. Muscovado was allowed to cool before weighing and packaging. For T2, the same procedure was followed using 1000 ppm lime. The weight of muscovado sugar produced from each treatment was recorded for the calculation of percent sugar yield.

2.5 Yield of Sugar

The weight of MJ used in processing muscovado and the weight of muscovado sugar produced were used in calculating the percent sugar yield per treatment combination using the formula:

$$\% \text{ Sugaryield} = \frac{\text{wt. of muscovado (kg)}}{\text{wt. of MJ (kg)}} \times 100$$

2.6 Physicochemical Analysis of Muscovado

Muscovado sugars produced from twenty treatment combinations were analyzed to determine their physicochemical properties such as moisture (MC), pol, ash, factor of safety (FS), sucrose, reducing sugar (RS), insoluble solids and color using the ICUMSA methods (PHILSUTECH, 1997).

2.7 Statistical Analysis

Data on lime concentration standardization such as juice pH, physicochemical properties and recovery data of mixed juice and muscovado sugar samples were subjected to Analysis of Variance (ANOVA) at 5% level of significance with the aid of a statistical software. Comparison of means was carried out through Waller-Duncan Test to locate significant difference among treatments.

3. Results and Discussion

3.1 Lime Concentration Standardization

Addition of 250 ppm lime gave a mean pH of 6.2 which is similar to control (6.1). Using 1500 ppm lime significantly resulted to a high MJ pH of 8.5, indicating that the concentration is too high. Among the five lime concentrations, 500 ppm and 1000 ppm significantly obtained a

mixed juice pH of 7.4 and 7.9 which is within the pH range of a clarified juice (PHILSUTECH, 1997). Based on the result, the use of 500 ppm up to 1000 ppm lime in juice clarification is enough to adjust the pH to neutrality. The pH range of mixed juice added with 500 ppm (pH 7.4) and 1000 ppm (pH 7.9) agrees with the pH values obtained by Farmani, et al. (2008) which ranged from 7.5 to 7.8. Moreover, the pH of limed mixed juice using 500 ppm and 1000 ppm is comparable to the standard range of clarified juice which is pH 6.9 to pH 8.0 (PHILSUTECH, 1997). Hence, 500 ppm and 1000 ppm lime concentrations were used as lime treatments in the study.

3.2 Physicochemical Properties of Mixed Juice

Phil 99-0925 recorded significantly the highest MJ brix of 13.79 °B (Table 1). No significant differences was observed in the brix of Phil 99-1793 (12.53 °B), VMC 85-484 (12.32 °B), VMC 86-550 (12.28 °B), VMC 84-524 (12.25 °B), and Phil 7464 (112.25 °B). The lowest MJ degreebrix was observed in Phil 2001-0295 (9.57°B). No significant difference was observed in the degree brix of VMC 87-95 and VMC 84-549 (11.17 °B and 11.08 °B).

Phil 99-0925 had the highest pol (12.16%) among the varieties (Table 1). No significant differences were observed in the pol values of Phil 99-1793 (11.32%), VMC 84-524 (11.05%), VMC 85-484 (11.01%), VMC 86-550 (10.88%) and Phil 7464 (10.88%). The lowest pol value was obtained from Phil 2001-0295 with the mean value of 8.33%. Based on the results, there was a similar trend observed in the percent pol values of mixed juice. Phil 99-0925 obtained the highest brix and pol among the samples. On the other hand, Phil 2001-0295 significantly obtained the lowest brix and pol with the mean values of 9.57 °B and 8.33%, respectively. This could be explained by the positive correlation of brix and pol values (correlation $r = 0.978$).

Mixed juice purity of Phil 2000-2569 (88.24%), VMC 85-484 (89.37%), VMC 86-550 (88.57%), Phil 99-0925 (88.17%) and Phil 7464 (88.76%) was comparable to each other (Table 1). This could be attributed to their high percent pol. Pearson correlation shows a positive correlation ($r = 0.978$) between mixed juice pol and purity. MJ having high pol also have high purity compared to MJ with low pol. Low purity was observed in VMC 87-95 (84.03%) and VMC 84-549 (82.94%). This might be due to the low pol of VMC 87-95 (9.38%) and VMC 84-549 (9.19%).

3.3 Physicochemical Properties of Muscovado Sugar

Table 2 and 3 shows the mean values of the physicochemical properties of muscovado sugar using 500 and 1000 ppm lime concentration, respectively. In using 500 ppm lime, Phil7464 obtained the highest mean pol of 91.23% while the lowest pol values were observed in VMC 87-95 (76.15%). No significant difference was observed in pol of VMC 84-524 (83.65%) and VMC 86-550 (83.76) as well as to Phil 99-1793 (78.06%) and VMC 84-549 (77.84%) in using 500 ppm lime. In using 1000 ppm, there was a significant variation in pol of muscovado samples (Table 3). Phil 7464 obtained the highest pol of 91.63%, while VMC 84-549 (78.54%) obtained the lowest. This could be attributed to the high MJ brix and purity of Phil 7464. Since pol is a direct measure of sucrose in sugar, this result implied that at least 1000 ppm lime is needed in clarifying the MJ to produce muscovado of high pol values.

Moisture is an unavoidable component of sugar therefore its control is very important. As shown in Table 2, there was a significant difference in MC of muscovado sugar among varieties. In using 500 ppm, the highest MC was obtained by Phil 2001-0295 (6.8%) while the lowest was in Phil 99-0925 (1.88%) and Phil 7464 (1.78%). Phil 7464 obtained significantly the lowest MC (1.45%) while the highest was obtained by Phil 99-1793 (6.04%) and VMC 86-550 (6.16%), respectively (Table 5). MC of T1 muscovado ranged from 1.78 to 6.8% while MC of T2 muscovado ranged from 1.45 to 6.16% (Tables 2 and 3). It was observed that MC range of T1 (using 500 ppm) is higher than T2 (using 1000 ppm). This implies the efficacy of using higher lime concentration in coagulating impurities in the juice and lowering the MC of muscovado sugar. When juice was decanted, water in clarified juice readily evaporated upon boiling, resulting to lower MC muscovado. Both T1 and T2 muscovado MC were quite high compared to the standard moisture content for raw sugar (0.5 to 0.7%) (PHILSUTECH, 1997). This is due to the difference in processing of muscovado and raw sugar. Muscovado is non-centrifugal sugar, while for raw sugar, centrifugation is an important process after crystallization.

The safety factor (SF) is a ratio used to indicate the keeping quality of raw sugar. The safety factor should not exceed 0.25. If SF exceeds 0.25 then sugar is prone to deterioration. As shown in Table 2, there was a highly significant difference of SF among ten varieties. There was no significant difference in the SF of muscovado of Phil 2000-2569 (0.29), Phil 99-1793 (0.25) and VMC 84-549 (0.3) as affected by variety. VMC 84-524 (0.34), VMC 86-550 (0.34), VMC

85-484 (0.34) and Phil 2001-0295 (0.33) were comparable in terms of SF as affected by variety. In Table 3, variety caused significant variation in the SF of T2 muscovado among varieties. No significant difference was observed in the SF of T2 muscovado from Phil 7464 (0.17) and VMC 87-95 (0.18). In comparison, Phil 7464, Phil 2000-2569 (0.25), VMC 85-484 (0.31), Phil 7464 (0.17), VMC 87-95 (0.18) and VMC 84-549 (0.25) of T2 had significantly better SF than T1 muscovado of some varieties (Tables 2 and 3). These findings imply that use of 1000 ppm in muscovado processing significantly improves the SF of the product. Based on SF values, T1 muscovado seemed more prone to deterioration than T2 muscovado. Although T2 muscovado had a safety factor range from 0.17 to 0.46, some of which are better than the standard (less than 0.25), still it can be inferred that juice liming at 1000 ppm is beneficial in prolonging the shelf life of muscovado.

Ash in sugar is the inorganic residue remaining after incineration. In routine sugar factory control, ash is usually determined only on the final molasses. Higher ash in raw sugar indicates the need for more steam, increased sucrose loss and product quality deterioration (Chen Chou, 1993). Table 2 showed a significant variation on the ash contents of muscovado among ten varieties. T1 muscovado of Phil 2001-0295 (3.29%), Phil 2000-2569(3.21%), Phil 99-1793(3.24%) and VMC 85-484(3.22%) obtained the highest ash contents. T1 muscovado of Phil 99-0925 (1.44%), Phil 7464 (1.33%) and VMC 87-95(1.65%) obtained the lowest ash contents (Table 4). T2 muscovado of Phil 7464 obtained the lowest ash content of 1.28% while T2 muscovado of Phil 2001-0295 (2.72%) obtained the highest ash content. T1 muscovado ash content ranged from 1.33 to 3.29% while T2 ranged from 1.7 to 2.72% (Tables 2 and 3). This implies the effectiveness of using higher lime concentration (1000 ppm) in reducing the ash content of muscovado sugar. Removal of impurities during juice clarification consequently lowered the ash content of the muscovado sugar. According to Albertson and Grof (2004), impurities in juice can be ash, dirt and sugars other than sucrose which affect crystallisation and sucrose recovery. Since ash is considered as impurity, the use of higher lime dosage (1000 ppm) is effective in reducing impurities in muscovado sugar.

The reducing sugars refer to the percentage of sugars other than sucrose like fructose and glucose in the juice. A lower reducing sugar value indicates that much of the sugars present are in the form of sucrose. Variety caused a significant variation on the reducing sugars of T1

muscovado (Table 2). T1 muscovado of VMC 86-550 obtained significantly the lowest reducing sugar of 2.07%. T1 muscovado of Phil 2001-0295 and Phil 2000-2569 obtained the highest reducing sugars of 5.38% and 5.80%, respectively. Variety caused significant variation of reducing sugar of T2 muscovado (Table 3). T2 muscovado of Phil 2000-2569 obtained the highest reducing sugar of 5.2% among varieties. No significant difference on reducing sugar was observed in varieties Phil 99-1793, VMC 85-484, VMC 84-524, Phil 99-0925, VMC 87-95 and VMC 84-549. Reducing sugar of T1 muscovado ranged from 2.07 to 4.89% while that of T2 ranged from 1.91 to 5.2%. This implies that the use of higher lime concentration of 1000 ppm lowered significantly the reducing sugars of muscovado.

Results showed a significant difference in sucrose contents of T1 muscovado among varieties (Table 2). T1 muscovado of Phil 7464 obtained the highest sucrose content of 92.71% while the lowest was recorded in VMC 87-95 (77.79 %). T1 muscovado of VMC 84-524(85.31%) and VMC 86-550 (85.47%) showed no significant difference in sucrose contents. Variety caused significant difference in sucrose contents of T2 muscovado (Table 3). The sucrose contents of muscovado using 1000 ppm ranged from 80.07% to 92.97% while muscovado using 500 ppm ranged from 77.79% to 89.45%. This implied that use of 1000 ppm lime increased the sucrose contents of muscovado. The difference in sucrose contents is attributed to the amount of reducing sugars present. T1 significantly have higher reducing sugar range than T2, hence T1 muscovado has lower sucrose contents than T2. Some sucrose was hydrolyzed to invert sugar due to the lower pH of T1 juice. The lower the reducing sugar present in muscovado, the higher is the amount of sucrose present in it. The low pH of T1 juice facilitated inversion to take place. In an acidic sugarcane juice, an increased amount of reducing sugar was observed due to sucrose hydrolysis (Hussain, et al., 2007).

In a conventional cane juice processing, the inefficient removal of substances like gum, ash, silica and colloids during clarification, adversely affects the color of the final product (Bhattacharya, et al., 2001). Color of the sugar crystals is an important factor that determines its market value and acceptability for various uses. Results showed a significant variation in ICUMSA color of T1 muscovado among varieties.. T1 muscovado from all varieties varied significantly in color except Phil 2001-0295 (2371 I. U.) and Phil 99-1793 (22657 I.U.) where no significant difference in color was observed. As shown in Table 3, there was significant

difference in ICUMSA color of T2 muscovado among varieties. T2 muscovado varied significantly in color except Phil 2000-2569 (27735 I.U.), Phil 7464 (27429 I.U.) and VMC 84-549 (27162 I.U.) where no significant difference in color was observed. Color of T2 muscovado ranged from 8,122 to 30,900 I. U. While color of T1 muscovado ranged from 9,850 to 39,567 I. U. (Tables 2 and 3). Impurities according to Albertson and Grof (2004) adversely affect crystallization; the higher is the color of sugar, the more impurities it contains. The use of only 500 ppm lime in juice clarification is not enough to reduce impurities and color. Higher lime concentration such as 1000 ppm is needed to reduce impurities and improve the color of muscovado.

The percent insoluble solids is the percentage by weight of insoluble materials in muscovado sugar. Sugarcane juice is clarified to remove the suspended insoluble solids to avoid adverse effect on the quality of sugar. The higher the insolubles present in sugar, the more prone it is to deterioration. Results showed a significant difference in the insolubles of T1 muscovado among varieties (Table 2). Variety caused no variation on the insoluble solids content of T1 muscovado from Phil 2000-2569 (0.95%), VMC 85-484 (0.8%), VMC 84-524 (0.74%), VMC 86-550 (1.02%), Phil 7464 (1.12%), VMC 84-549 (1.07%) and Phil 99-0925 (0.98%). No significant difference was observed in the insolubles of T1 muscovado from varieties Phil 2001-0295 (0.31%) and Phil 99-1793 (0.27%) as affected by variety. Variety caused significant variation on the insoluble solids content of T2 muscovado (Table 3). Muscovado sugar of Phil 99-0925 (1.04%) and VMC 87-95 (1.06%) significantly obtained highest insolubles among muscovado sugar treated with 1000 ppm lime (T2). Insolubles of T2 muscovado ranged from 0.2 to 1.06% while T1 muscovado ranged from 0.27 to 1.26%. (Tables 2 and 3). The lower insolubles range value of T2 muscovado implies use of higher lime concentration of 1000 ppm lime lowered the impurities of muscovado. According to Egglestone et al. (2002), the aim of clarification is to remove the maximum quantity of impurities in the mixed juice at the earliest stage. Juice clarification has a great impact on boiling house operations, sugar yield, and refining quality of raw sugar. The less insolubles the mixed juice have before evaporation, the better is the quality of sugar because the quality of sugar depends upon the quality of the juice (Hussain, et al., 2007).

3.4 Muscovado Sugar Yield

Results showed a significant variation on sugar yield of T1 muscovado among varieties (Table 4). Similarly, variety caused a significant variation on the sugar yield of T2 muscovado. There was a significant difference in sugar yield of T1 muscovado from all varieties except in Phil 2000-2569 (8.97%), Phil 99-1793 (8.93%), VMC 85-484 (9.03%) and VMC 84-549 (8.53%). There was a significant difference in sugar recovery of T2 muscovado from all varieties except in Phil 2000-2569 (9.17%), VMC 85-484 (9.22%) and VMC 84-549 (8.66%). T2 muscovado yield ranged from 8.66 to 11.10% while T1 muscovado yield ranged from 8.53 to 10.83%. The higher sugar yield range of T2 implies that it is advantageous to use 1000 ppm than 500 because impurities are significantly reduced and sugar yield is increased. Impurities present in the juice affect sugar yield. During sucrose formation, the impurities adsorbed on the crystal surface have a retarding effect on crystal growth (Shiau, 2003). In addition, Fourmond (1966) emphasized that however efficient milling and boiling techniques may be, some sucrose are immobilized by the impurities of the juice. Impurities adversely affect crystallization and sucrose recovery (Albertson and Grof, 2004).

Of the varieties, T2 muscovado of VMC 84-524 obtained the highest muscovado yield of 11.1% among the treatments. The high yield of muscovado in VMC 84-524 is due to cane quality. VMC 84-524 had a high MJ brix and purity. On the contrary, T1 muscovado of Phil 2001-0295 (8.53%) and VMC 84-549 (8.53%) obtained the lowest yields. The low sugar yields of these varieties are attributed to its low MJ brix and pol. This goes to show that quality canes produce quality muscovado with higher sugar yield. Pearson correlation analysis showed strong positive correlation between sucrose and sugar yield ($r = 0.670$), pol and sugar yield ($r = 0.662$). It can be inferred that brix and pol in the MJ has a great bearing in the sugar yield of muscovado.

3.5 Suitable Varieties and Lime Concentration for Quality Muscovado

To succeed in muscovado production, it is important to choose the right sugarcane variety and lime concentration to produce quality muscovado. The choice of a high yielding sugarcane variety is a great factor that necessitates production of quality muscovado. To demand a better price in the market, muscovado producers should see to it that their product conforms to standards. Muscovado should have lower MC, SF, RS, ash and insoluble solids content. Moreover, muscovado should have high sucrose content and sugar yield. Based on the findings

of the study, Table 5 specified the suitable sugarcane varieties at a given lime concentration in the production of quality muscovado.

To obtain muscovado with high percent pol, Phil 7464 is the most suitable variety using both 500 and 1000 ppm lime concentration. For lower moisture content and safety factor muscovado, at 500 ppm, Phil 99-0925 and Phil 7464 can be used. At 1000 ppm, VMC 87-95 and Phil 7464 can be utilized. For low ash and high sucrose content, at 1000 or 500 ppm, Phil 7464 is most ideal. At 500 ppm, Phil 99-0925, VMC 87-95 and Phil 7464 can be used.

For low reducing sugars and insolubles, varieties that are good to use at 500 ppm lime are VMC 86-550, Phil 2001-0295 and Phil 99-1793. At 1000 ppm, Phil 7464 and Phil 99-1793 can be used. Sucrose content in sugar is one of the most important qualities that determine the price of the product. The higher the sucrose content, the higher is the quality of muscovado sugar. To attain high sucrose content and muscovado sugar yield, Phil 99-0925, VMC 84-524 and VMC 86-550 can be used at 500 ppm lime. At 1000 ppm, Phil 7464 can be used to obtain high sucrose content and high muscovado sugar yield.

4. Conclusion

Standardization of lime concentration revealed that 500 and 1000 ppm can neutralize the mixed juice pH to pH 7.4-7.9 which is within the standard range. Among the varieties, Phil 99-0925 recorded significantly the highest mixed juice brix and pol while the lowest was in Phil 2001-0295. A positive correlation existed between pol and purity. Varieties having high pol also have high purity as the case of Phil 2000-2569, VMC 85-484, VMC 86-550, Phil 99-0925 and Phil 7464. The physicochemical characterization of muscovado sugar processed using two lime treatments-500 and 1000 ppm and ten sugarcane varieties facilitated the determination of suitable varieties at particular lime levels to produce muscovado of good quality. Both lime concentration and sugarcane variety caused significant differences in the yield and physicochemical properties of muscovado sugar. Either 500 or 1000 ppm lime concentration at specific varieties can be used to obtain quality muscovado. The six most suitable varieties to use for muscovado processing are; Phil 7464, VMC 84-524, VMC 86-550, VMC 87-95, Phil 99-0925 and Phil 2001-0295.

Table 1: Mean¹ values of the physicochemical properties of Mixed juice (MJ) of sugarcane varieties

SUGARCANE VARIETY	BRIX (°B)	POL (%)	PURITY = $\frac{\text{Pol}}{\text{Brix}} \times 100$ (%)
Phil 2001-0295	9.57 a	8.33 a	87.06 b
Phil 2000-2569	10.14 b	8.95 b	88.24 c
Phil 99-1793	12.53 d	11.32 c	90.33 d
VMC 85-484	12.32 d	11.01 c	89.37 cd
VMC 84-524	12.25 d	11.05 c	90.15 d
VMC 86-550	12.28 d	10.88 c	88.57 c
Phil 99-0925	13.79 e	12.16 d	88.17 c
Phil 7464	12.25 d	10.88 c	88.76 c
VMC 87-95	11.17 c	9.38 b	84.03 a
VMC 84-549	11.20 c	9.38 b	84.03 a

¹N=3. Means followed by the same letter(s) in a row are not significantly (P≤0.05) different from each other.

Table 2: Mean¹ values of the physicochemical properties of muscovado sugar using 500 ppm lime concentration

SUGARCANE VARIETY	PHYSICOCHEMICAL PROPERTIES							
	POL (%)	MOISTURE (%)	FS	ASH (%)	SUCROSE (%)	REDUCING SUGAR (%)	COLOR (I.U.)	INSOLUBLES (%)
Phil 2001-0295	81.03 d	6.80 d	0.33 f	3.29 d	82.65 d	5.38 g	23371 bc	0.31 a
Phil 2000-2569	78.30 c	6.34 c	0.29 de	3.21 d	80.03 c	5.80 g	31791 d	0.95 b
Phil 99-1793	78.06 b	5.45 b	0.25 c	3.24 d	79.53 bc	4.89 f	22657 bc	0.27 a
VMC 85-484	83.10 e	5.81 b	0.34 f	3.22 d	84.65 e	3.97 e	29850 a	1.01 b
VMC 84-524	83.65 f	5.64 b	0.34 f	2.16 b	85.31 f	3.49 d	24758 c	1.06 bc
VMC 86-550	83.76 f	5.51 b	0.34 f	2.67 c	85.47 f	2.07 a	21527 b	1.02 b
Phil 99-0925	87.97 g	1.88 a	0.15 a	1.44 a	89.45 g	2.62 c	30342 d	0.98 b
Phil 7464	91.23 h	1.78 a	0.20 b	1.33 a	92.71 h	2.36 bc	29518 d	1.12 bc
VMC 87-95	76.15 a	6.33 c	0.26 cd	1.65 a	77.79 a	3.53 de	39567 f	1.26 c

VMC 84-549	77.84 b	6.58 cd	0.30 e	2.64 c	79.03 b	3.34 d	34055 e	1.07 bc
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¹N=3. Mean values with the same letter(s) in a column are not significantly ($P \leq 0.05$) different from each other.

Table 3: Mean¹ values of the physicochemical properties of muscovado sugar using 1000 ppm lime concentration

SUGARCANE VARIETY	PHYSICOCHEMICAL PROPERTIES							
	POL (%)	MOISTURE (%)	FS	ASH (%)	SUCROSE (%)	REDUCING SUGAR (%)	COLOR (I.U.)	INSOLUBLES(%)
Phil 2001-0295	84.23 e	5.28 c	0.33 d	2.72 d	85.83 d	4.63 d	17977 c	0.15 a
Phil 2000-2569	80.33 c	5.03 c	0.25 b	1.76 b	80.11 a	5.20 e	27735 d	0.71 c
Phil 99-1793	79.86 b	6.04 d	0.29 c	2.40 cd	81.38 b	3.79 c	17923 c	0.20 a
VMC 85-484	83.23 d	5.28 c	0.31 cd	1.70 b	84.84 c	3.07 bc	28122 a	0.80 c
VMC 84-524	84.13 e	5.25 c	0.33 d	2.02 bc	85.97 d	2.62 b	18872 c	0.74 c
VMC 86-550	84.20 e	6.16 d	0.39 e	1.93 b	85.85 d	1.91 a	13924 b	0.56 b
Phil 99-0925	89.40 f	4.86 c	0.46 f	1.76 b	90.90 e	3.52 bc	29773 e	1.04 d
Phil 7464	91.63 g	1.45 a	0.17 a	1.28 a	92.97 f	2.11 a	27429 d	0.80 c
VMC 87-95	80.42 c	3.58 b	0.18 a	1.96 b	81.83 b	3.34 bc	30900 e	1.06 d

VMC 84-549	78.54 a	5.33 c	0.25 b	2.06 bc	80.07 a	3.78 c	27162 d	0.86 c
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¹N=3. Mean values with the same letter(s) in a column are not significantly ($P \leq 0.05$) different from each other.

Table 4: Mean¹ values of yield (%) of muscovado sugar at different lime concentrations

SUGARCANE VARIETY	LIME CONCENTRATION	
	T1 – Yield (%)	T2 – Yield (%)
Phil 2001-0295	8.53 a	8.66 a
Phil 2000-2569	8.97 c	9.17 d
Phil 99-1793	8.93 c	9.03 c
VMC 85-484	9.03 c	9.22 d
VMC 84-524	10.83 e	11.10 a
VMC 86-550	10.03 d	10.33 f
Phil 99-0925	10.03 d	10.17 e
Phil 7464	10.10 d	10.53 g
VMC 87-95	8.73 b	8.87 a
VMC 84-549	8.53 c	8.66 a

¹N=3. Means followed by the same letter(s) within a column are not significantly ($P \leq 0.05$) different from each other. T1 = 500 ppm; T2 = 1000 ppm

Table 5: Suitable sugarcane variety (ies) and lime concentration to use to produce quality muscovado

PARAMETER	VARIETIES AT LIME CONCENTRATION	
	500 ppm	1000 ppm
High % pol muscovado sugar	Phil 7464	Phil 7464
Low % MC muscovado sugar	Phil 99-0925 Phil 7464	Phil 7464 VMC 87-95
Low FS muscovado sugar	Phil 99-0925 Phil 7464	Phil 7464 VMC 87-95
Low % ash muscovado sugar	Phil 99-0925 Phil 7464 VMC 87-95	Phil 7464
High sucrose content muscovado sugar	Phil 99-0925 VMC 84-524 VMC 86-550	Phil 7464
Low % reducing sugar muscovado sugar	VMC 86-550	VMC 86-550 Phil 7464
Low insolubles muscovado sugar	Phil 2001-0295 Phil 99-1793	Phil 99-1793
High sugar yield	VMC 84-524	Phil 7464

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