J. Food and Dairy Sci., Mansoura Univ., Vol. 10(4): 131 - 134, 2019

Effect of Imbibition Rate on Milling Quality of some Sugar Cane Varieties

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ABSTRACT

This study aimed to determine the effect of imbibition rate on milling quality and extracted juice for fresh green and burnt cut cane stored for different periods of two cane varieties Giza 99/103 and Giza 99/160 during 2016/ 2017 working season., both varieties were planted under comparable conditions at Kom Ombo Sugar Cane Research Station Farm, Aswan Governorate, Egypt. The obtained results revealed that every rise in imbibition of 5% cane and or 42.7 % fiber, there was an increase of about 4.7 and 0.9 % in mixed juice and pol extraction; respectively in Giza 99/103 while Giza 99/160 were 4.7 and 1.0 %. Pol % bagasse decreased by 0.55, 0.48 and 0.35 for every 5 % increase in imbibition rate from 20 to 35 % with the variety Giza 99/103. The variety Giza 99/160 showed a slight increase in mixed juice and pol extractions over Giza 99/103.In case of Giza 99/103 variety, fiber % cane increased from 11.7 in fresh green cane to 12.7, 12.9 and 13.4 after 2, 4 and 6 days from burning and cutting; respectively. The levels of imbibition rate % fiber were found to be; 157.5, 196.9, 236.2 and 275.6; respectively of 2 days storage period. After 4 days they become 155.0, 193.8, 232.6 and 271.3 whereas after 6 days imbibition levels % fiber was: 149.3, 186.6, 223.9 and 261.2, while the burnt cut cane of Giza 99/160 variety showed the same pattern. The increase in fiber content % cane was 1.8, 1.9 and 2.9 over the fresh cane after 2, 4 and 6 days storage periods; respectively. The presented data showed that brix and pol % mixed juice (sugar percent in mixed juice) had increased from day to day with all imbibition rate level used. Mixed juice purity decreased slightly with time elapse and so was the increase in glucose ratio and non-pol % brix (non sugars percent in brix) with fresh green and burnt cut cane stored for 6 days after harvest of both varieties.

Keywords: sugar cane, imbibition, milling quality, extraction, burnt cane, loss in bagasse

INTRODUCTION

Cane is widely cultivated in tropical and temperate regions like Upper Egypt where is planted on the narrow strip of land along the banks of the Nile. In Egypt, the sugar industry is located in an arid area with a short cold dry winter and a long hot dry summer. The milling season starts in December and ends late in May and approximately half the season lies in the hot summer. In 2017/2018 harvested cane area increased by nine percent or 10,000 ha, to reach 119,000 ha, which to produce about 13.650 million ton of sugar cane, cane area harvested in 2016/2017 was 109,000 ha, producing 12.580 million ton of sugar cane (Anon, 2018). The government's policy of encouraging farmers to grow beets over sugar cane as a water saving measure has been ineffective

Imbibition is the process in which water or juice is added to bagasse to dilute the juice present in the bagasse, the water so used is termed imbibition water. General terms in use are single imbibition, double imbibition, compound imbibition, depending on the manner in which the water and/or juice is added. Imbibition rates vary widely with country, systems of extraction, the capacity of the mill, cane varieties and their fiber contents and mainly the relative costs of sugar and fuel (Peacock SD *et al*, 2009). Preharvest burning of sugar cane is a common practice in some countries to facilitate mechanical harvesting or to increase the efficiency of manual cutters. Due to the fragmentation of the area under cane, preharvest burning is not easy to control; yet unplanned preharvest burning results in undesirable changes in cane quality especially when milling is delayed after burning and cutting. Among these changes are high sugar losses in final bagasse (Sayed *et al*, 1977).

This investigation aimed to study the effect of imbibition rate on milling quality and extracted juice of fresh green and burnt cut cane stored for different periods of two cane varieties namely Giza 99/103 and Giza 99/160 during 2016/ 2017 working season.

MATERIALS AND METHODS

Materials:

The first and third ratoon cane of the two varieties Giza 99/103 and Giza 99/160 were used in these tests during 2016/ 2017 working season; both varieties were planted under comparable conditions at Kom Ombo Sugar Cane Research Station Farm, Aswan Governorate, Egypt.

Methods:

Green fresh cane sample were prepared to analysis where cane stalks were hand stripped and cleaned as described by Sayed (1977). The clean samples were sub-sampled to 30 kgs. Burnt cut cane samples stored under open filed conditions for a period of six days, were secured as described by Hemaida (1975).

Mixed juice extraction with different imbibition rates:

The mixed juices of the different treatments were extracted by the pilot mill. The imbibition rates applied were 20, 25, 30 and 35% clean cane and each imbibition water rates was replicated four times. Green fresh cane and burnt cane stored for 2, 4 and 6 days after burning and cutting were tested twice during February and May. Each sample was first crushed, and the resultant bagasse was dry milled two times. Then, the amount of imbibition water (cold or hot) for each treatment was divided into three equal portions, and sprinkled on the bagasse using a hand sprinkler before each of the three last successive crushers. The resultant mixed juice was screened and weighted, and then sampled. The final bagasse was also sampled for pol analysis.

Juice extraction from cane; prepared bagasse, and bagasse leaving the diffuser:

Samples of cane, prepared bagasse for diffuser, first mill bagasse and bagasse leaving the diffuser were dry milled by the pilot mill for the last attainable juice drop (this was achieved through 5 crushes). Both the resultant juice and bagasse were weighted and sampled for pol (sugar percent) determination. Final bagasse samples were analyzed for pol%, the pol% cane, pol % bagasse and pol% bagasse leaving the diffuser were calculated as follows:

Pol% cane =

$$\frac{pol\%\ juice \times wt.of\ juice + pol\%\ bagasse \times wt.of\ bagasse}{wt.of\ cane\ sample} \times 100$$

Pol% prepared bagasse =

$$\frac{pol\%\ juice \times wt.of\ juice + pol\%\ bagasse \times wt.of\ bagasse}{wt.of\ bagasse\ sample} \times 100$$

Pol% bagasse leaving the diffuser =

$$\frac{pol\%\ juice \times wt.of\ juice + pol\%\ bagasse \times wt.of\ bagasse}{wt.of\ cane\ sample} \times 100$$

Methods of analysis:

1- Fiber content % cane was determined as described in the official methods of control and analysis for Mauritius sugar factories (1970).

2- Fiber content % final bagasse, pol % final bagasse and all the data of the 10 days factory technical report were determined according to the Egyptian Sugar and Distillation Company Chemical Control (1954).

3- Juice analysis for apparent total soluble solids, pol % juice reducing sugar and ash by conductivity according to the methods described by Meade and Chen (1977).

Calculation:

The following methods of calculations were used throughout this study:

1- Pol % cane, pol in prepared bagasse % cane, pol in bagasse leaving the diffusion % can and pol lost in final bagasse % cane were calculated according to Meade and Chen (1977).

2- The milling quality parameters, namely, mixed juice % cane, pol extraction % pol in cane, pol losses in final bagasse % pol in cane and imbibition % fiber together with juice quality parameters, purity, glucose ratio, reducing sugar % brix were calculated according to Meade and Chen (1977).

3- Hugot (1972) reported the following parameters to express and compare milling work efficiency:

a) Pol % bagasse: but this depends on richness or sugar content of the cane and moisture content of the bagasse as much as on efficiency of the mill.

b) Milling loss: takes into account the moisture content of the bagasse:

$$\textbf{Milling loss} = \frac{pol\%\ bagasse \times 100}{fiber\ bagasse}$$

c) Extraction: this figure expresses essentially the efficiency:

$$\textbf{Extraction} = \frac{pol\ in\ mixed\ juice \times 100}{pol\%\ cane}$$

d) Extraction ratio: this figure corrects for both sugar in cane and its fiber content.

$$\textbf{Extraction ratio} = \frac{100(100 - extraction)}{fiber\%\ cane}.$$

4- To measure the limit of variation in non-pol through processing, the following ratios were calculated:

a) Non-pol % brix (Hugot, 1972).

b) Non-pol % ratio (Rouillard, 1979).

Where:

pol = sugar percent and no-pol = non sugar percent

RESULTS AND DISCUSSION

The average fiber content % clean cane and imbibition rates % fiber corresponding to varying imbibition levels % cane were calculated in the two varieties under study. Data in tables (1) and (2) show the average milling qualities of both varieties as affected by the different levels of imbibition. In both varieties, mixed juice extraction rose markedly as the imbibition level increased, while pol extraction showed slight increase. Pol % final bagasse and pol losses in final bagasse % pol in cane and percent cane decreased at a lesser rate. Final bagasse % cane seemed to be unaffected by increasing imbibition level, being more or less constant. The patterns of these changes were similar in both varieties. For every rise in imbibition of 5% cane and or 42.7 % fiber, there was an increase of about 4.7 and 0.9 % in mixed juice and pol extraction; respectively in Giza 99/103 while the corresponding figures for Giza 99/160 were 4.7 and 1.0 %. Pol % bagasse decreased by 0.55, 0.48 and 0.35 for every 5 % increase in imbibition rate from 20 to 35 % with the variety Giza 99/103, similar trend was found with Giza 99/160 variety but with lesser values.

Table 1. Milling qualities of Giza 99/103 variety fresh green cane as affected by different imbibition rates.

Imbibition level % cane	Fiber content % cane	Imbibition rate % fiber	Mixed juice content% cane	Pol extraction	Pol content % bagasse	Bagasse content % cane	Loss in bagasse	
							% pol content in cane	% cane
20	11.7	170.9	83.9	90.6	4.47	36.2	9.4	1.72
25		213.7	88.1	91.5	4.19	37.0	8.5	1.56
30		256.4	91.8	92.2	3.71	38.3	7.8	1.41
35		299.0	97.9	93.2	3.36	37.4	6.8	1.26

The variety Giza 99/160 showed a slight increase in mixed juice and pol extractions than of Giza 99/103 and hence a decrease in pol losses in final bagasse. Such observation could be attributed to the fact that Giza 99/103 is characterized by initially higher pol % cane relative to variety Giza 99/160. Many investigators reported similar conclusion (Kent, 2001 and Rein, 2007).

Table 2. Milling qualities of Giza 99/160 variety fresh green cane as affected by different imbibition rates.

Imbibition level % cane	Fiber content % cane	Imbibition rate % fiber	Mixed juice content% cane	Pol extraction	Pol content % bagasse	Bagasse content% cane	Loss in bagasse	
							% pol content in cane	% cane
20	11.7	170.9	84.2	91.5	3.79	35.9	8.5	1.37
25		213.7	88.3	92.2	3.37	37.0	7.8	1.25
30		256.4	93.3	93.4	3.02	35.8	6.6	1.08
35		299.0	98.2	93.5	2.85	36.9	6.5	1.08

The effect of higher imbibition levels and higher extraction on mixed juice quality obtained from both Giza 99/103 and Giza 99/160 cane varieties shown in table (3). It is observed that mixed juice purity and non-pol % brix were more or less constant under all imbibition levels used. This result is in agreement with that of Fernandes, 2003 and Loubser, 2004 whose stated that for a given cane purity, mixed juice decreased and non-pol % brix increased as the imbibition level and hence extraction increased. Such result may be attributed to the use of clean trash-free cane and the simple imbibition adopted in applying imbibition water.

Data in Tables (4) and (5) show the effect of varying imbibition rates on milling quality of burnt cut cane stored for different periods after burning and cutting. Data in tables show that fiber content of burnt cut cane tended to increase was accompanied by a decrease in both mixed juice and pol extractions and hence a high sugar losses of final bagasse. Also the ratio of imbibition water to fiber decreased due to the increase in fiber % cane.

Table 3. Mixed juice quality parameters of Giza 99/103 and Giza 99/160 varieties as affected by different imbibition rates.

Imbibition level %cane	Brix		Pol		Purity		Glucose ratio		Non-Pol % brix	
	99/103	99/160	99/103	99/160	99/103	99/160	99/103	99/160	99/103	99/160
20	21.60	19.28	19.54	17.38	90.5	90.2	1.0	2.5	9.5	9.8
25	21.70	18.51	18.83	16.69	91.0	90.2	1.2	2.5	9.0	9.8
30	21.21	18.03	18.31	16.24	90.7	90.1	1.2	2.4	9.3	9.9
35	19.10	17.20	17.31	15.03	91.0	90.4	1.2	2.8	9.0	9.6

Table 4. Milling quality of Giza 99/103 burnt cut cane stored for different periods as affected by different imbibition rates.

Storage periods (days)	Imbibition level % cane	Fiber content % cane	Imbibition level % fiber	Mixed juice % cane	Pol (sugar) extraction	Pol content % bagasse	Bagasse % cane	Loss in bagasse	
								%pol cane	% cane
2	20	12.7	157.5	81.7	90.1	4.72	38.4	9.9	1.82
	25		196.9	85.3	90.9	4.19	39.6	9.1	1.68
	30		236.2	90.1	91.6	3.83	39.9	8.4	1.56
	35		275.6	94.6	92.4	3.51	40.5	7.6	1.44
4	20	12.9	155.0	79.3	89.0	5.10	40.9	11.0	2.08
	25		193.8	83.6	90.0	4.56	41.5	10.0	1.91
	30		232.6	88.0	90.8	4.17	42.1	9.2	1.77
	35		271.3	93.4	91.5	3.91	41.7	8.5	1.64
6	20	13.4	149.3	76.6	86.7	5.89	43.4	13.3	2.62
	25		186.6	81.3	87.9	5.40	44.5	12.1	2.46
	30		233.9	83.5	87.8	5.18	47.4	12.2	2.49
	35		261.2	90.6	89.9	4.44	44.5	10.1	2.02

Table 5. Milling quality of Giza 99/160 burnt cut cane stored for different periods as affected by different imbibition rates.

Storage periods (days)	Imbibition level % cane	Fiber content % cane	Imbibition level % fiber	Mixed juice % cane	Pol extraction	Pol content % bagasse	Bagasse % cane	Loss in bagasse	
								% pol cane	% cane
2	20	13.5	148.1	80.0	90.2	3.92	40.0	9.9	1.58
	25		185.2	85.1	90.8	3.62	40.0	9.2	1.48
	30		222.2	89.7	91.7	3.26	40.4	8.3	1.32
	35		259.3	93.5	92.3	2.92	41.6	7.7	1.21
4	20	13.6	147.1	79.2	89.5	4.22	40.8	10.4	1.75
	25		183.8	82.9	90.6	3.62	42.2	9.4	1.54
	30		220.6	88.6	91.4	3.40	41.5	8.4	1.44
	35		257.3	93.8	92.3	2.89	41.2	7.7	1.34
6	20	14.6	144.9	78.4	88.7	4.59	41.7	11.3	1.98
	25		171.2	83.3	90.4	3.90	41.2	9.6	1.69
	30		205.5	88.5	90.9	3.69	41.5	9.1	1.59
	35		239.7	91.8	91.6	3.36	43.2	8.4	1.51

In case of Giza 99/103 variety, fiber content of cane increased from 11.7 % in fresh green cane to 12.7 %, 12.9 % and 13.4% after 2, 4 and 6 days of burning and cutting cane ; respectively. Converting the levels of imbibition cane (which were: 20, 25, 30 and 35) to imbibition fiber, they were found to be; 157.5, 196.9, 236.2 and 275.6; respectively of or 2 days storage period. After 4 days they become 155.0, 193.8, 232.6 and 271.3 whereas after 6 days imbibition levels % fiber was: 149.3, 186.6, 223.9 and 261.2. The decrease in imbibition level % fiber had its ill effect on both mixed juice and pol extractions and hence pol losses in final bagasse, with constant imbibition cane, i.e. 3.6 %, as where fiber % cane increased by 1.7 after six days storage over the fresh cane, the recorded decrease in mixed juice and pol extractions was 7.3 and 2.6; respectively. The corresponding sugar losses in final bagasse % cane increased by 0.76 (Kent, 2010a).

The burnt cut cane of Giza 99/160 variety showed the same pattern. The increase in fiber % cane was 1.8, 1.9 and 2.9 over the fresh cane after 2, 4 and 6 days storage periods; respectively. With 35 % cane imbibition rate at the sixth days and due to 2.9 % increase in fiber % cane, mixed juice and pol extraction were lowered by 6.3 % and 1.9 %; respectively, whereas sugar losses in final bagasse showed an increase of 0.45 (Kent, 2010b).

Comparing the behavior of two varieties with respect to changes in fiber % cane, mixed juice and pol extractions and sugar losses in final bagasse % cane with time elapse after burning and cutting cane with 35 % cane imbibition levels it was found that although Giza 99/160 variety showed higher increase in fiber % cane than Giza 99/103 (2.9 and 1.7), the reduction in its mixed juice and pol extractions (6.3 and 1.9) were less than those of Giza 99/103 (7.3 and 2.6), and so was the being lower with Giza 99/160 (0.45) then with Giza 99/103 (0.76). such reverse response could be attributed to varietal differences, mainly pol % cane which was initially higher in Giza 99/103 (19.60) than in Giza 99/160 (17.18). These results are in general agreement with those reported by Lamusse and Munsamy (1979).

These results emphasize the importance of milling burnt cane as soon as possible after harvest, to avoid the increase in fiber content due to dryness under the local hot dry weather, especially at the last third of the milling season. If cane grinding delay is expected, the ratio of imbibition water to cane fiber content should be kept around 300 to maintain high extraction figures.

Tables (6) and (7) show the effect of varying imbibition rates on the mixed juice quality of burnt cut cane stored for 6 days after harvest. Due to high moisture loss from burnt cut cane, mixed juice brix and pol tended to increase as the storage period extended. On the other hand pol % mixed juice underwent slight deterioration.

Table 6. Mixed juice quality parameters of fresh green and burnt cut cane upon storage as affected by varying imbibition rates, variety Giza 99/103.

Storage periods (days)	Imbibition level % cane	Brix	Pol %	Purity	Glucose ratio	Non-pol % brix
Zero	20	21.60	19.54	90.5	1.0	9.5
	25	20.7	18.83	91.0	1.2	9.0
	30	20.21	81.31	90.7	1.2	9.3
	35	19.10	17.31	91.0	1.2	9.6
2	20	22.34	20.03	89.7	1.4	10.3
	25	21.52	19.37	90.2	1.4	9.8
	30	20.59	18.49	89.9	1.5	10.1
	35	20.25	18.22	90.1	1.4	9.9
4	20	23.65	21.06	89.3	1.8	10.7
	25	22.58	20.21	89.5	1.9	10.5
	30	21.98	19.58	89.2	1.9	10.8
	35	20.95	17.71	89.4	1.8	10.6
6	20	24.48	21.75	88.9	2.4	11.1
	25	24.04	21.44	89.2	2.4	10.8
	30	23.85	21.09	88.5	2.7	11.5
	35	21.73	19.31	88.9	2.6	11.1

Also data in Tables (6) and (7) show that brix and pol % mixed juice had increased from day to day with all imbibition level used. Mixed juice purity decreased slightly

with time elapse and so was the increase in glucose ratio and non-pol % brix. All these parameters within time of analysis were kept more or less unaffected by the different levels of imbibition used with either fresh or burnt cut cane. Such findings could be attributed to the fact that clean cane was used in this test, thus avoiding the effect of field inert on the mixed juice quality (Wienese, 1995).

Table 7. Mixed juice quality parameters of fresh green and burnt cut cane upon storage as affected by varying imbibition rates, variety Giza 99/160.

Storage periods (days)	Imbibition level % cane	Brix	Pol %	Purity	Glucose ratio	Non-pol % brix
Zero	20	19.28	17.38	90.2	2.5	9.8
	25	18.51	16.69	90.2	2.5	9.8
	30	18.03	16.24	90.1	2.4	9.9
	35	17.20	15.53	90.4	2.8	9.6
2	20	20.03	17.93	89.6	2.37	10.4
	25	19.03	17.00	89.3	2.53	10.7
	30	17.97	16.11	89.3	2.84	10.7
	35	17.28	15.44	89.4	2.87	10.4
4	20	20.87	18.53	88.9	3.1	11.1
	25	19.91	17.64	88.6	3.2	11.4
	30	19.07	16.95	88.8	3.2	11.2
	35	18.68	16.74	89.7	3.0	10.3
6	20	22.00	19.39	88.1	3.1	11.9
	25	21.21	18.70	88.1	3.2	11.9
	30	19.95	17.56	88.1	3.4	11.9
	35	19.00	17.49	88.3	3.4	11.4

CONCLUSION

Finally it could be concluded that every rise in imbibition rate of cane (%) and or fiber content (%), there was an increase in mixed juice and pol extraction in both varieties, while Pol % bagasse decreased for every increase in imbibition rate with the variety Giza 99/103. The variety Giza 99/160 showed a slight increase in mixed juice and pol extractions over Giza 99/103.

In case of Giza 99/103 variety, fiber % cane increased in stored burning and cutting cane than fresh green cane therefore the levels of imbibition % fiber were found to be increasing from day to day of stored burning cut cane, while the burnt cut cane of Giza 99/160 variety showed the same pattern.

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تأثيرمعدل التخفيف على جودة الاستخلاص لبعض أصناف قصب السكر

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تم عمل هذا البحث لتقدير تأثير التخفيف بالماء على جودة إستخلاص العصير لصنفين من قصب السكر هما جيزة 103/99 وجيزة 160/99 الخام وبعد الحرق والتخزين لفترات مختلفة خلال موسم إستخلاص 2016/ 2017م وتم زراعة صنفى القصب تحت ظروف محطة أبحاث قصب السكر بكوم امبو محافظة أسوان، مصر. ومن النتائج المتحصل عليها تبين أن كل زيادة فى معدل التخفيف بالماء % قصب بمعدل 5% أو 42.9% الياف يكون هناك زيادة بمقدار4.7% و0.9 % فى العصير الخليط ودرجة الحلاوة المستخلصة فى الصنف جيزة 103/99 بينما كانت 4.7 % و 1.0 % للصنف جيزة 160/99. وسجلت درجة الحلاوة % الباجاس إنخافضا قدره 0.55 ، 0.48 و 0.35 % مع كل زيادة فى معدل التخفيف قدرها 5% من 20 إلى 35% للصنف جيزة 103/99. الصنف جيزة 160/99 اظهر زيادة طفيفة فى العصير الخليط والحلاوة المستخلصة عن الصنف جيزة 103/99. نسبة الالياف % قصب للصنف جيزة 103/99 زادت من 11.7 فى القصب الخام إلى 12.7، 12.9 و13.4 بعد 2، 4 و 6 أيام تخزين بعد حرقه وكسره على التوالى. بينما وجد معدل التخفيق % الياف ,157.5، 196.9، 236.2 و 275.6 على التوالى بعد يومين من التخزين. ووصلت معدل التخفيف بعد 4 ايام تخزين إلى 155، 193.8، 232.6 و 271.3 اما بعد 6 ايام تخزين كان معدل التخفيف % ألياف: 149، 186.6، 223.9 و 261.2، بينما أظهر الصنف جيزة 160/99 بعد حرقه وكسره زياده فى نسبة الالياف % قصب حيث سجلت 1.8، 1.9 و 2.9 عن القصب الخام بعد فترة تخزين 2، 4 و 6 أيام على التوالى. كذلك أظهرت النتائج أن درجة البركس والحلاوة % للعصير الخليط زيادة من يوم لاخر مع كل معدلات التخفيف المستخدمة. ونقاوة العصير الخليط قلت بمعدل طفيف مع مرور الوقت وبالتالى زيادة فى معدل الجلوكوز ونسبة المواد الغير السكرية % بركس للقصب الخام والمحروق فى كلا الصنفين موضع الدراسة.

J. Food and Dairy Sci., Mansoura Univ., Vol. 10(4): 131 - 134, 2019