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Physicochemical Quality of Ethiopian Plantation White Sugar from Three Sugar Factories

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Abstract- Quality differences among the three Ethiopian plantation white sugars from *Metahara*, *Finchaa* and *Wonji* sugar factories and refined sugar (control) in reference to the carbonated soft drink industry requirements were evaluated. Degree of pol (^oZ), sucrose (%), color (IU), turbidity (IU), pH, reducing sugar (%) and SO_2 (mg/kg) for the three sugar samples were: 99.73–99.79, 99.73–99.79, 210-271, 181–210, 6.59-6.82, 0.032-0.083 and 10.60–13.11, respectively, and for the control sugar sample were: 99.94, 99.94, 36, 10, 7.21, 0.076 and 0.00, respectively. Conductivity ash (%), moisture (%), dextran (mg/kg), insoluble matter (mg/kg), particle size (mm), iron (mg/kg), copper (mg/kg) and lead (mg/kg) contents were: 0.012-0.018, 0.010-0.023, 72-78, 82.67-118.67, 0.90-1.02, 0.97-1.56, 0.26-0.42 and 0.11-0.30, respectively and for the control sugar sample were: 0.003, 0.013, 74.67, 4.67, 0.65, 0.21, 0.13 and 0.11, respectively. The three plantation white sugars have certain quality differences like pol, color, SO_2, reducing sugar, iron, copper and lead contents. Sugars from *Finchaa* and *Metahara* have exhibited almost similar and better quality than *Wonji* possibly on the account of high pol and sucrose, lower- SO_2, insoluble matter and turbidity. Although the three sugar samples met the Codex *Alimentarius* standards set for the plantation white sugars and some quality requirements of the soft drink industry, there are still limitations particularly on pol, SO_2, color, turbidity and insoluble matter for direct use in the carbonated soft drink industries.

Index Terms- *Finchaa*; *Metahara*; Physicochemical quality; Plantation white sugar; Soft drinks; and *Wonji*

I. Introduction

Sugar cane (*Saccharum officinarum*) is the major raw material for the production of sugar. In the cane sugar processing four key operations are involved: extraction of raw juice, purification, evaporation, and crystallization. The end-product, raw sugar, is about 96.0-98.5% sucrose, which is further refined to remove the remaining impurities to the extent that the final product is 99.9% sucrose (Rein, 2008). Sugar is principally used as a sweetener, but also as filler and preservative. Its industrial users include bakeries, manufacturers of: confectioneries, pharmaceuticals, soft drinks, vegetable canneries and dairy. Sugar makes about 10% of the soft drinks content. Carbonated soft drinks account 45% of sugar consumption in the soft drink industries (Shachman, 2005).

Sugar quality features such as color, polarization, sulfur dioxide, iron, lead, arsenic, ash, moisture content, total suspended matter, invert sugar, turbidity, particle size, flocks, odor, taste, total bacteria, yeast and mould counts are commonly used to evaluate the quality of sugar for the carbonated soft drink productions (Shachman, 2005; Eggleston et al 2003; Hamerski et al. 2012; Eggleston et al. 2011). These quality features are affected by many factors such as variety, maturity level of the cane, weather conditions, diseases, growing-harvesting conditions, cut-to-crush delay and by the processing technology used (Godshall *et al.*, 2002; Hamerski et al. 2012; Eggleston et al. 2011). Although plantation white sugar is acceptable as a food, it has certain limitation to fulfill the requirements of certain users, for example carbonated beverage, pharmaceutical manufacturers, canners and confectionery manufacturers that requires high degree of purity that can be satisfied from the refined sugar or more recently from direct white sugar products (Rein, 2008). Particularly, the carbonated soft drink industries, which have strict quality requirement is a potential market for the Ethiopian sugar industries. But the carbonated soft drink industries are importing huge amount of refined sugar from abroad that meets their quality standards. This is mainly because of some quality limitations in the plantation white sugars that can impair their production processes and the final soft drink quality. Some of the common defects in the soft drink industries that can be related with poor sugar quality are formation of acid flocks (turbidity), alteration of flavor, color and taste (Steindl and Doherty, 2005).

Currently, the Ethiopian Government is building modern sugar factories and expanding the existing ones with the aim of maximizing the production volume to alleviate the current scarcity of sugar in the country (EIA, 2008). This work was conducted in view of the limited information on quality evaluation of Ethiopian plantation white sugar with reference to the carbonated soft drinks, canners and pharmaceutical requirements. Thus, in this work, physicochemical properties of the plantation white sugars from *Metahara*, *Finchaa* and *Wonji*, Ethiopia in reference to the requirements of carbonated soft drinks are reported.

II. MATERIALS AND METHODS

Experimental site

All physicochemical quality analysis except the trace metals were conducted at the Ethiopian Sugar Development Agency, Sugar and Ethanol Technology Laboratory, *Wonji*.

Trace metal analysis were conducted at Haramaya University, Ethiopia.

Collection of samples

Annual composite plantation white sugar samples from *Metahara*, *Finchaa* and *Wonji* sugar factories produced in 2009/2010 working season was collected from Ethiopian Sugar Development Agency, Sugar and Ethanol Technology Laboratory, Wonji, Ethiopia. Control sample, imported refined sugar from the United Sugar Company, Saudi Arabia, which is in use by the East Africa Bottling Share Company under the approval of *Coca Cola* International was collected from the East Africa Bottling Share Company, Dire Dawa Plant, Dire Dawa, Ethiopia. Information on processing technology and cane varieties used at the three sugar factories were collected using semi-structured questionnaires.

Polarization (^oZ)- was determined by Automatic Saccarometer (Model: AUTOPOL 880, SN: 80851, USA) using a light source 589.44 nm (yellow) according to ICUMSA method GS1/2/3-1 (1994).

Sucrose content (%)- was determined after dissolving 52.0 g sugar sample and employing lead acetate as clarifying agent by Automatic Saccarometer (Model: AUTOPOL 880, SN: 80851, USA) taking reading before and after inversion of the sample with hydrochloric acid according to AOAC (1990).

$$Sucrose(\%) = \frac{100\,(P-I)}{132.56 - 0.0794\,(13-m) - 0.53\,(t-20)}$$

Where: P= direct reading, normal solution; I= invert reading, normal solution; t = temperature at which readings was made; m=g total solid from original sample in 100 mL invert solution

Color (IU)-was measured at absorbance of 420 nm according to ICUMSA method GS 1-7 (1994) and the value was expressed in ICUMSA Units (IU).

Turbidity (IU) -was determined according to SMRI Test methods TM025 (2004) as ICUMSA color absorbance (420 nm) difference between unfiltered and filtered (0.45 µm cellulose nitrate membrane) solutions after dissolving sugar sample (50 g/100 mL) in distilled water.

The p**H** of sugar solution (50g/100g concentration) was determined using glass electrode attached to pH meter (Model: 3P, INDIA) after calibration at pH 4.00, 7.00 and 9.00 at 20^{O}C following ICUMSA method GS1/2/3/4/7/8-23 (1994).

Reducing sugar content (%)-was determined by Lane and Eynon constant volume titrametric method of ICUMSA method GS1/3/7-3 (1994).

Sulfite content (mg/kg) was determined by measuring absorbance at 560 nm with UV–VIS spectrophotometer (Model: Light wave II, SN: 109888, UK) for both sample and standard sulfite sugar solutions of sulfite/rosaniline complex color that were developed by reaction of decolorized rosaniline solution in the presence of formaldehyde by ICUMSA method GS2-33 (1994). Amount of SO_2 in each sample was estimated from the standard calibration curve.

$$\text{mg SO}_2 / kg\ sugar = \frac{\mu g\ \text{SO}_2\ from\ graph\ x\ 10}{mass\ of\ \ sugar\,(g)}$$

Conductivity ash (%) -Inorganic, soluble ash content was determined by measuring electrical conductivity with conductivity meter (Model: seven easy, SN: 1229305224, CHINA) at 20±0.2 ^{O}C after dissolving sugar sample (31.3 g/100 mL) in distilled water according to ICUMSA method GS2/3-17 (1994).

Moisture content (%)- was determined as mass loss on drying (105 ±1^{O}C) for 3 h in an air forced drought oven (Model: MIDO/3/CLAD) according to ICUMSA method GS2/1/3-15 (1994).

Dextran content (mg/kg)- was determined by ICUMSA method GS1-15 (1994) after removal of interferences (starches with α-amylase and protein by trichloroacetic acid precipitation and filtration) and formation of haze by dextran upon addition of denatured absolute ethanol. Absorbance of the haze formed was measured at 720nm for both sample and standard dextran solutions and dextran content was then estimated from the standard calibration curve.

Insoluble matter content (mg/kg) was determined by membrane filtration method as the increase in the mass of membrane filter after dissolving sugar sample in hot distilled water, filtration (membrane filter of pore size 8.0 µm, 50 mm diameter), washing and drying in an oven (Model: MIDO/3/CLAD) at 63^{O}C for 3 h according to ICUMSA method GS2/3-19 (1994).

Particle size distribution (mm) -was determined by sieving method according to ICUMSA method GS2-37 (1994).

Iron, Copper and Lead

The Fe, Cu and Pb contents was determined by Flame Atomic Absorption Spectroscopy (Model: 210 V GP, SN: 687, USA) methods (Leblebici and Volkan, 1998) after digestion of sugar sample (100 g). Standard solutions were prepared for iron from pure iron wire, copper from copper wire and lead from lead nitrate in the range 0-12mg/L, 0-5mg/L and 0-5mg/L, respectively. The levels of Fe, Cu and Pb were estimated from their respective standard calibration curves after measuring the absorbance (nm) for both samples and standards at 248.33, 324.75 and 283.31, respectively.

Data analysis

At least a triplicate data were analyzed for analysis of variance (ANOVA) by SAS (2002) statistical analysis software version 9.0, 2002, SAS Institute Inc., Cary, NC, USA and mean differences were compared using Duncan's Multiple Range Tests (DMRT) at $p<0.05$. Data collected from questioners were analyzed qualitatively.

III. RESULTS AND DISCUSSION

Polarization (pol, ^oZ)

The pol for the three plantation white sugar samples had varied between 99.73–99.79 (Table 1). Among the plantation white sugar samples, the highest pol was for *Finchaa* and the least was for *Wonji*. The pol for the control sugar sample meets minimum pol 99.9^{o}Z set for refined sugar (USC, 2008) and was significantly ($p<0.01$) higher than for the three plantation white sugars. *Wonji* had significantly different pol value than *Finchaa* and *Metahara*. The pol values of the plantation white sugars obtained in this work are in the range 99.5-99.8 reported by Rein *et al.* (2007) and also meets the minimum codex standard of 99.5 ^{o}Z for plantation white sugar (Codex, 2001). Pol is a measure of sucrose purity and carbonated soft drink manufacturers require $\geq$ 99.9 ^{o}Z (USC, 2008). Thus, none of the plantation white sugar samples meet the pol requirement of the carbonated soft drink industries.

Sucrose

The sucrose content of the three plantation white sugar samples had varied from 99.73 to 99.79 % with the highest being for *Finchaa* (99.79%) and *Metahara* (99.79%) and the least was for *Wonji* (99.73%) (Table 1). Sucrose content for the control sugar sample was 99.94% and was significantly higher ($p<0.01$) than the three plantation white sugar samples. The sucrose content of the three plantation white sugars was in the range 99.50 to 99.80 % (Rein et al. 2007), but higher than 99.33 to 99.55% reported by El-Syiad (2000) for Egyptian plantation white sugar. High percentages of sucrose indicate high purity and lower impurities. Thus in terms of sucrose content, the three plantations white sugar are still inferior as compared to the control refined sugar.

Color

There is a significant difference in color among the sugar samples ($p<0.01$) (Table 1). The plantation white sugar colors were high (210 to 271 IU) (*Finchaa* > *Wonji* > *Metahara*) as compared to for the control sugar sample (36 IU) (Table 1). The plantation white sugar color was in the range 80 to 250 IU except for *Finchaa* (Steindl and Doherty, 2005), lower than 477 to 667 IU (El-Syiad, 2000) but was higher than 10 to 80 IU (Trott, 1988) and the Codex (2001) recommendation of ≤ 150 IU. Color to the sugar is contributed from plant pigments (polyphenols-such as flavonoids, phenolic acids, phenolic glucosides and phenylpropanoids), from a process induced color formations (melanoidins, caramels and alkaline degradation products of fructose) and by the factors that can impair color removal (residual dextran, heavy metal, pH, processing temperature and sulfitation efficiency) (Okuno and Tamaki, 2002; Hamerski et al. 2012). Dextran can increase the viscosity of the juice and thereby reduces filtration, crystallization and impair color removal efficiency (Godshall et al. 2001). Strong correlations was observed between color and trace metals (copper, iron and lead) contents because trace metals like iron will reacts with phenolic compounds and contribute to the formation of dark brown color (Table 2). The relatively high color in *Finchaa* sugar sample may be contributed by high dextran (Table 3), high iron and copper than in the *Metahara* and *Wonji* sugar samples (Table 4). Carbonated soft drink manufacturers demand the maximum color of the sugar to be ≤ 45 IU (USC, 2008). None of the samples from the local sugar factories satisfied the color requirements of the carbonated soft drink industries.

Turbidity

The turbidity had varied from 181 to 210 IU for the three plantation white sugars and the highest was for *Wonji* and the least was among *Metahara* and *Finchaa* (Table 1). The turbidity of the three sugar samples were significantly different ($p<0.01$) from the control sugar sample (10 IU). The turbidity found for the three samples and control was in the range 100 to 500 IU and 10 to 30 IU, respectively (Trott, 1988). Strong correlation ($r= 0.951$) was observed between turbidity and color since as color increases, the non-sugar contents that contributes to the turbidity also increases (Table 2). Turbidity is one main parameter used to assess the clarification process performance because it is related to the presence of non-sugar, flocks and suspended formation contributing materials such as starch, dextran and other indigenous sugar cane polysaccharides, gums and proteins in the juice (Hamerski et al. 2012). The removal of turbidity indicates the removal of these components. Soft drink bottlers demand non-foaming sugar without turbidity and the plantation white sugar from the three sugar factories are limited in this aspect to meet the requirements of soft drink industries.

pH

The sugar pH had varied significantly ($p<0.01$) among the three plantation white sugars and ranged from 6.59 (*Finchaa*) to 6.82 (*Metahara*) (Table 1). The control refined sugar has the highest pH value (7.21). Control of pH has a considerable importance because at low pH below 7.0 there is a sucrose losses by inversion and at high pH greater than 9.0 there can be an increase in the color because of trace reducing sugars degradations (Hamerski et al. 2012). The difference in pH among the sugar samples could be related to the variation in liming and sulphitation degrees on the clarification of the juice.

Reducing sugar

There was significant difference ($p<0.01$) among the three plantation white sugars and the control sugar sample on their reducing sugar (RS) contents (*Finchaa* > control > *Metahara*> *Wonji*) (Table 3). The RS content of white sugar was reported in the range of 0.01-0.10% (Trott, 1988). The requirement of carbonated soft drink manufacturers for RS content is 0.1% (USC, 2008) and all sugar samples can satisfy this requirement. The RS content had a positive ($r=0.784$) and negative ($r= -0.612$) correlations with dextran and sulfite contents, respectively (Table 2). If there is high RS, with storage of such sugar, there can be an increase in the color via caramelization and Maillard reactions.

Sulfite content

There was a significant difference ($p<0.01$) among the three plantation white sugars samples on their sulfite contents (*Wonji* > *Metahara* > *Finchaa*) (Table 3). The control sample had insignificant (virtually 0 mg/kg) sulfite content. The least sulfite content found in *Finchaa* sugar sample as compared to the other two sugars indicates, the sulfite application may be reduced or the processing in the production of this sugar is somewhat had suppressed the sulfite content since the *Finchaa* sugar bears the highest color (271 IU). According to ICUMSA (1994) the sulfite content of plantation white sugar can range from 5 to 15 mg/kg and the maximum level recommendation by Codex is 70mg/kg (Codex, 2001). The result showed that all samples from the three sugar factories can meet the codex recommendations but are limited to meet the carbonated soft drink industry demand of maximum 6 mg/kg sulfite (USC, 2008).

Conductivity ash

The conductivity ash was significantly ($p<0.01$) varied among the sugar samples (*Metahara* > *Wonji* > *Finchaa* > control sample). The conductivity ash showed a strong correlation with copper (r=0.507), iron (r=0.734) and lead (r=0.510) contents (Table 2). Conductivity ash is contributed from inorganic cations (calcium, magnesium, potassium), anions (chloride, phosphate, nitrate, nitrite, sulphate and sulphite) and ionized acids supplied to the factory from the soil associated with harvested sugar cane, sugar cane tissues (leaf and stem tissues) and lime added during the juice clarification process (Eggleston et al. 2011). High conductivity ash in the sugar is a characteristic of lower purity of lower economic value (Hamerski et al. 2012). The conductivity ash contents of the three sugar samples can meet the codex maximum of ≤ 0.1% (Codex, 2001), but except for *Finchaa* and the control sugar samples, the other samples from the two factories are limited to meet the carbonated soft drink manufacturers requirement of ≤ 0.015% (USC, 2008).

Moisture

The moisture content had varied significantly ($p<0.01$) among the sugar samples (Table 3) and the highest (0.023%) was found in *Finchaa* and the lowest (0.010%) was for *Wonji*. Moisture content below 0.15 % is generally considered satisfactory (Starzak, and Mathlouthi, 2011). All the sugar samples had moisture level that lead to safety factor limit of < 0.25. This condition is not conducive for micro-organisms growth to cause spoilage and sucrose losses (Starzak, and Mathlouthi, 2011). The carbonated soft drink manufacturers require maximum moisture content of ≤ 0.04% (USC, 2008) and the Codex (2001) standard for plantation white sugar is ≤ 0.1%. Thus, the moisture content of the three plantation white sugar samples satisfies both the carbonated soft drink industry requirements and the Codex standards.

Dextran

There is a significant difference ($p<0.05$) among sugar samples on the dextran contents (*Finchaa* > control >*Metahara* and *Wonji*) (Table 3). The dextran contents (71.87 to 78.40 mg/kg) found for the sugar samples were less than 141 to 374 mg/kg (El-Syiad, 2000) and 224 to 928 mg/kg (Godshall et al., 2001) reported for the plantation white sugar. Dextran (molecular weight from 1500 to the order of 10^6 Da) is a polymer of glucose synthesized from sucrose by the action of microorganisms dextransucrase enzyme secreted by *Leuconostoc mesenteroides*, *Streptococcus* and *Lactobacillus* (Kaur and Kaler, 2008; Aquino and Franco, 2009). The predominant microorganism implicated for dextran formation in the sugar cane industry is *Leuconostoc* species- ubiquitous in sugar cane filed (Aquino and Franco, 2009). These enter the cane at places of exposed tissue caused by machine harvesting, cutting, burning, freezing, disease and pests. The presence of dextran indicates a lost sugar and is enhanced under wet conditions of temperature greater than 25^{O}C. Dextran in the juice, syrups and sugars can lead to false pol reading (i.e., 1000mg/kg dextran can enhance pol reading by 0.3^{o}) (Kaur and Kaler, 2008). Dextran concentrations greater than 500 mg/kg in raw sugar juice can cause processing problems, such as increased viscosity, slowed filtration, crystal distortion and sucrose losses (Kaur and Kaler, 2008; Aquino, and Franco, 2009). In the alcoholic and soft drinks industries, the presence of dextran could lead to the formation of haze and precipitations in the products and spoilage in other food industries, such as candy and chocolate manufacture (Aquino and Franco, 2009). In soft drink industry there is a suggestion to use dextran because of its use in drugs especially as blood plasma volume expander (Bhavani and Nisha, 2010).

Insoluble matter

The insoluble matter contents of the sugar samples had varied significantly ($p<0.01$) among the three plantation white sugars samples between 82.67 (*Finchaa*) to 118.67 mg/kg (*Wonji*) (Table 4). The control sugar had very low insoluble matter (4.67 mg/kg). The insoluble matters are predominately alcohol flocks comprising organic and appreciable amounts of inorganics. Soft drink bottlers require a maximum of 10 mg/kg insoluble matter content in the sugar sample (USC, 2008). Thus, except the control sample, none of the plantation white sugar samples met this requirement.

Particle size

The particle sizes (mean) of the three plantation white sugars samples are coarse and had varied from 0.90 mm to 1.02mm. There is a significant difference between the control sugar sample particle size (0.65 mm) and the three sugar samples ($p<0.01$) (Table 4). According to Baikow (1982), an acceptable sugar particle size range is from 0.6-1.0 mm, while the preferred size is 0.8 mm (i.e., all sugar samples were in accordance with this recommendation).

Trace elements (Fe, Cu and Pb)

There was a significant difference ($p<0.01$) in iron (Fe), copper (Cu), and lead (Pb) contents of the plantation white sugar samples (Table 4). The Fe, Cu and Pb contents (mean) in the plantation white sugars had ranged from 0.97 to 1.56 mg/kg, 0.26 to 0.42 mg/kg and 0.11 to 0.30 mg/kg, respectively. For the control sugar sample, these values were 0.21 mg/kg, 0.13 mg/kg and 0.11, respectively. High Fe and Cu contents were found in *Finchaa* sugar sample. Lead content was high in *Metahara*. Carbonated soft drink manufacturers like Coca Cola require maximum of 1 mg/kg for Fe and Cu and 0.1 mg/kg for Pb (USC, 2008). Therefore, among plantation white sugar samples, only *Wonji* can satisfy the maximum allowable trace metal limits, whereas *Metahara* and *Finchaa* couldn't meet the Fe and Pb limits required by carbonated soft drink manufacturers. The Fe, Cu and Pb contents found in the three plantation white sugar samples were less than those reported (Mohamed, 1999) (Fe = 0.16 mg/kg, Cu = 14.00 mg/kg and Pb = 4.00 mg/kg) for Egyptian plantation white sugar (sucrose 99.7%). In addition to the soil upon which the sugar cane is cultivated, minerals were reported to be contributed by the processing equipment used in the plantation white sugar production. There was good correlation of color with Cu, Fe and Pb contents (Table 2). This may be due to the reaction of trace metals with color precursor trace compounds of the cane to give dark color (Godshall et al 2001).

Processing technology and sugar cane variety utilized among the three local factories

Using semi-structured questionnaire, information on the sugar cane variety and processing technology difference was collected from professionals of the three respective factories. The number of sugar cane varieties grown and milled at *Metahara*, *Finchaa* and *Wonji* farm were 6, 11 and 12, respectively. Although there is a difference among the factories farm, some common varieties like B-52298 and NCO-334 were also grown in all the sugar farms. Sugar cane milling in Ethiopia is not done on variety bases. At *Metahara* cane varieties B 52298, MEXICO 54/245 and NCO 334 are often crushed together. At *Wonji* B 52298, NCO 334 and N 14 are often crushed together. At *Finchaa* B 52298 and NCO 334 are often crushed together. Among these, MEXICO 54/245 were described by one factory respondents as poor in quality in terms of color, pol, ash and reducing sugar. If other factors are not limiting, it is an advantage to reduce the number of different sugarcane varieties crushed together to reduce the variety effect on the processing. There is a difference on the soil types used in the cultivation. At *Metahara* the soil was vertisol, clay loam and sandy soil. At *Wonji* are heavy clay, sandy loam and sandy brown soils and at *Finchaa* is Luvi and loam soil. Such variation might also contribute to the difference in the plantation white sugar quality. The three sugar factories virtually exercise similar processing technology and process monitoring experiences. However, there are some differences that can affect the quality of the final sugar to be different. Sugar cane is washed before milling by *Finchaa* by use of pressurized water through spray nozzles. Such washing may improve the quality with respect to soil mineral load, water soluble impurities and debris provided water used may not load additional minerals. There is a difference on cane varieties crushed together. At *Metahara* cane varieties B 52298, MEXICO 54/245 and NCO 334 are often crushed together. In terms sulphitation techniques, at *Metahara* simultaneous sulphitation, at *Wonji* pre-liming and at *Finchaa* shock liming are used. Such sulphitation and liming application differences are known to contribute to the slight variations on the quality of plantation white sugar quality differences (Eggleston et al. 2003; Hamerski et al. 2012).

IV. CONCLUSIONS

In this study, the physicochemical properties of three Ethiopian plantation white sugar samples (*Metaharaa*, *Finchaaa* and *Wonji)* were evaluated in reference to the carbonated soft drink industry requirements. A significant difference on polarization, SO_2, color and insolube matter was found among the three sugar samples. Sugar samples from *Finchaa* and *Metahara* have exhibited almost similar and better quality standards than *Wonji* possibly on the account of high polarization and sucrose, lower SO_2, insoluble matter, turbidity and flocks contents. The three plantation white sugar samples although met some quality requirements of the carbonated soft drink manufacturers, there are considerable limitations, particularly on polarization, SO_2, color and insoluble matters. Also there are limitations for *Finchaa* and *Metahara* plantation white sugar samples in the iron and lead contents and for *Metahara* and *Wonji* sugar samples in flocks content to meet the demanded of carbonated soft drink industries.

Considering the high demand of refined sugar locally together with export of raw sugar to European Union and complaints from carbonated soft drink industries, further refining technology plant annexed to one of the existing sugar factories is important both to add value to meet the requirements of soft drink and other industry demands for the refined sugar.

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Table 1. Physicochemical quality (polarization, sucrose content, color, turbidity and pH) of plantation white sugar from three (*Finchaa*, *Metahara* and *Wonji)* factories and the control sugar sample

Sugar type	pol±SD (°Z)	SC±SD (%)	CO±SD (ICUMSA)	TU±SD (IU)	pH±SD (pH)
Finchaa	99.79±0.01[b]	99.79±0.01[b]	271±1.32[a]	181.0±5.99[b]	6.59±0.056[d]
Metahara	99.78±0.02[b]	99.79±0.01[b]	210±2.20[c]	186.0±7.18[b]	6.82±0.050[b]
Wonji	99.73±0.01[c]	99.73±0.01[c]	236±3.11[b]	210.4±4.95[a]	6.73±0.015[c]
Control	99.94±0.01[a]	99.94±0.01[a]	36.0±1.65[d]	10.0±1.64[c]	7.21±0.015[a]
DMRT (p<5%)	***	***	***	***	***
CV	0.01	0.01	0.96	2. 60	0.57

Values in the same column followed by the same letter do not differ significantly at 5% probability; *** =significant at 1% probability level; DMRT =Duncan Multiple Range Test, CV= Coefficient of Variation; pol = Polarization; SC = Sucrose Content; CO =Color; TU=Turbidity; IU=ICUMSA Units and Control= Coca Cola company approved refined sugar sample imported from Saudi Arabia

Table 2. Pearson correlation coefficients for pol, SC, CO, IM, RS and CA

	DX	TU	Cu	Fe	Pb	SO_2
Pol	0.199	-0.983***	-0.685**	-0.767**	-0.324	-0.971***
SC	0.200	-0.975***	-0.693**	-0.753***	-0.285	-0.959***
Color	0.107	0.951***	0.908***	0.935***	0.513	0.917***
I.M.	-0.293	0.983***	0.635**	0.743***	0.333	0.982***
RS	0.784***	-0.555	0.125	-0.071	0.099	-0.612**
CA	-0.411	0.938***	0.507	0.734***	0.510	0.975***

**= P< 0.05; ***=P< 0.01; Pol = Polarization (°Z); SC = Sucrose Content (%); Color IU); IM= Insoluble Matter (%); RS =Reducing Sugar (%); CA= Conductivity Ash (%); DX= Dextran (%); TU= Turbidity (IU); Cu, Fe and Pb (mg/kg) = Copper Iron and Lead, respectively and SO_2(mg/kg) = sulfur dioxide

Table 3. Physicochemical quality (RS, SO_2, conductivity ash, moisture and dextran contents) of plantation white sugar from three (*Finchaa*, *Metahara* and *Wonji)* sugar factories and the control sugar sample

Sugar sample	RS (%)	SO_2(mg/kg)	CA (%)	MC (%)	Safety factor	DX (mg/kg)
Finchaa	0.083±0.002a	10.60±0.056c	0.012±0.00002c	0.023±0.001a	0.11	78.40±1.62a
Metahara	0.045±0.001c	12.88±0.028b	0.018±0.0002a	0.011±0.001c	0.05	71.87±1.62b
Wonji	0.032±0.001d	13.11±0.032a	0.016±0.0002b	0.010±0.001c	0.04	71.87±1.62b
Control	0.076±0.002b	0.00±0.016d	0.003±0.0001d	0.013±0.001b	0.22	74.67±1.62b
DMRT (p<5%)	***	***	***	***		**
CV	3.08	0. 42	1.21	4.58		2.44

Values in the same column followed by the same letter do not differ significantly at 5% probability; ***=significant at 1% probability level; DMRT =Duncan Multiple Range Test, CV = Coefficient of Variation; RS=Reducing Sugar; SO_2= Sulfur dioxide; CA=Conductivity Ash; MC=Moisture Content; DX =Dextran and Control= Coca Cola company approved refined sugar sample imported from Saudi Arabia

Table 4. Physicochemical quality (insoluble matter, particle size, iron, copper and lead) of plantation white sugar from three (*Finchaa*, *Metahara* and *Wonji*) factories and the control sugar sample

Sugar type	IM±SD (mg/kg)	PS±SD (mm)	Fe±SD (mg/kg)	Cu±SD (mg/kg)	Pb±SD(mg/kg)
Finchaa	82.67±1.15[c]	1.02±0.006[a]	1.56±0.026[a]	0.42±0.01[a]	0.25±0.015[b]
Metahara	95.33±1.15[b]	0.90±0.006[c]	1.29±0.026[b]	0.26±0.01[c]	0.30±0.008[a]
Wonji	118.67±1.15[a]	0.99±0.006[b]	0.97±0.026[c]	0.28±0.01[b]	0.11±0.008[c]
Control	4.67±1.15[d]	0.65±0.006[d]	0.21±0.026[d]	0.13±0.01[d]	0.11±0.008[c]
DMRT (p<5%)	***	***	***	***	***
CV	0.77	0.73	2. 91	1.92	5.88

Values in the same column followed by the same letter do not differ significantly at 5% probability; ***=significant at 1% probability level; DMRT =Duncan Multiple Range Test, CV = Coefficient of Variation; IM = Insoluble Matter; PS = Particle Size; Fe, Cu and Pb= Iron, Copper and Lead, respectively.