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SUGAR CONTENT, PH, AND WEIGHT OF FOUR GERMPLASMS OF CASHEW APPLE (*ANACARDIUM OCCIDENTALE* LINN.) FRUITS GROWN UNDER TWO AGRO-ECOLOGICAL ZONES IN GHANA

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ABSTRACT

Changes in climatic conditions are associated with changes in the physicochemical properties of many fruits. Four germplasms of cashew apple originating from Brazil, Tanzania, Ghana (herein referred to as local) and Mozambique but all grown in Ghana were studied to assess the effect of agro-climatic zones on the sugar accumulation, pH, and weight of these cashew apples. Cashew apples were sourced from experimental stations in Bole and Wenchi in the Northern and Savannah regions of Ghana, respectively. A total of 1800 fruits were used for the experiment. Inter and intra significant differences ($P < 0.05$) were scored amongst germplasms collected from both locations concerning the measured parameters. Sugar ranged between 8.7% - 12.5% with fruits from Bole having the highest sugar content. The pH value ranged from 3.9 (Local germplasm from Bole) – 4.3 (Tanzania germplasm from both locations). The weight ranged between 33 g (Tanzania germplasm from Bole) – 69.8 g (Brazil germplasm from Bole). Meteorological data (from February 2017- April 2018) collected from both locations influenced the parameters, thus associating with the fruits from both locations. Conclusively, the present study indicated that, weather and geographical locations had effect on sugar content, pH, and weight of cashew apples.

Keywords: Cashew apple, sugar content, germplasm, agro-climatic zone, weight

Introduction

Cashew (*Anacardium occidentale* Linn.) is believed to have originated from Brazil in South America and Latin America (Pennington *et al.,* 2004). It belongs to the family Anacardiaceae. Cashew apple is cultivated in the Northern (Guinea and Sudan) savannah, Forest savannah (Transitional zone), and Costal savannah areas in Ghana. Cashew plant varies in sizes ranging from shrubs to big plants and low input is needed for its production, hence a more profitable venture for farmers (Attri, 2009). It is a seasonal crop with its major season beginning from January to April in both Northern (Guinea and Sudan) savannah and Forest savannah (Transitional zone) (Ministry of food and agriculture, 2006). The Northern savannah has a unimodal rain fall pattern while the Forest savannah experiences bimodal rainfall pattern (Bennett-Lartey *et al.,* 2008).

Thae apple is regarded as an agricultural by-product from harvesting the nuts. Ghana has been producing and exporting the dry nuts of cashew which is the main commercial industrial activity (Lowor & Agyente-Badu, 2009). The juice that is in the apple contains about 10 % (w/v) total sugar and it can be converted into alcohol of reasonable quantities (Joseph, 2010). Hence, it has been suggested that cashew apple genetic stock with high sugar content will be more economical for the alcoholic beverage producing companies (Lowor & Agyente-Badu, 2009).

Due to the high tannin content, the apple does not have any economic value as compared with the nut hence left to rot on the field (Akinwale, 1999). The nuts are harvested, processed, and exported. Recently, there has been a major increase in research on cashew nut but not much attention has been paid to the cashew apple. The cashew apple has a huge potential for juice and wine production as well as being marketed as fruits if a genetic tock with high sugar and low tannin content is bred or discovered.

The study seeks to identify those germplasms that have an appreciable sugar content that the consuming market will accept as fruit which will give additional income to the farmers engaged in cashew production. Furthermore, the study evaluated whether agro climatic conditions influence the sugar content, weight, and pH of the germplasms.

Experimental

Plant material collection and experimental set-up

The study was conducted at Bole in the Savannah region and Wenchi in the Bono region. Matured cashew apples from different genetic stock (Brazil, Mozambique, Tanzania, and Ghana {local}) were collected from the Cocoa Research Institute of Ghana, Bole and Wenchi Agricultural Station under Ministry of Food and Agriculture (MOFA) in the Savannah and Wenchi Regions, respectively.

A complete randomised designed was used in which 200 fruits were selected from 10 trees at random from each germplasm at Bole and Wenchi with a total of 1800 fruits avoiding trees from the borders of the fields. The harvesting was done by plucking 20 fruits per tree from each germplasm. The samples were washed with distilled water and package in plastic baskets of different labels (having the names of each germplasm) on the field. The cashew samples were then packed in an agro-transporting vehicle and then sent to the laboratories of Cocoa Research Institute of Ghana, Bole and Wenchi Agricultural Stations for further analysis. The sugar content, pH, and weight of the freshly harvested and transported cashew germplasm were measure the same day of harvest at these laboratories.

Determination of sugar content, weight, and pH

Sugar content was measured using an Anpro Beer Wort and Wine portable refractometer (serial code: AWR1-1-AP and X0017LUZHF, China). Brix [20% sugar (sucrose) solution] and distilled water were used to calibrate the scale of the refractometer following the manufacture's protocol. In summary, the sugar percentage of distilled water (Refractive Index=1.333) was read as "0" or 0% Brix and that of the 20% sugar solution as 20% BRIX. Subsequently, the sugar percentage of the cashew germplasms were measure and recorded as % brix since one-degree Brix equals one gram of sugar per 100 g of solution, or 1% sugar. The cashew apples were crushed and about two to three drops of the pure extracted juice were dropped on the main prism of the refractometer with a dropper. After each reading, the main prism of the refractometer was cleaned with a soft damp cloth and the dropper rinsed with distilled water.

The weight of cashew apples was determined using a calibrated Kern and Sohn GmbH electronic weighing scale (WD100043902, D-72336 Balingen, Germany).

The pH was determined using a Jellas Pocket size pH meter (X00058X7CD, China). The pH meter was calibrated with buffers 4, 7 and 10. The calibrated electrode was dipped in the extracted juice and the readings were taken accordingly. The electrode was rinsed with distilled water before using it for the next sample.

Data analysis

Data was analysed using GenStat® Version 12 (VSN International, UK) and Correlation Analysis done using Microsoft excel 2010. Statistical differences were accepted at $P < 0.05$. Standard errors were used to indicate differences, measuring the likelihood of the data to be from the true population mean. Bonferroni test was used to sperate the significant means during the statistical analysis. Graphs were created using Microsoft excel 2010.

Results and discussion

The sampling was done from February to March 2018 for both locations because that was the peak season for Cashew harvesting. It was observed that Cashew germplasms from both locations were Red or Yellow in colour. In few cases, some of the fruits had orange colour which may be due to blends and interbreeding between trees with different colours of fruits which causes colour segregations within the subsequent generations (Dan *et al*, 2017). For this study, the apples were bulked together without separating them into different colours. There was significant difference ($P < 0.05$) amongst all the cashew apple germplasms collected from both locations in terms of their sugar content with Local germplasm from Bole recording the highest sugar content (12.5%) whilst Mozambique germplasm from Wenchi recorded the lowest (8.7%) (Table 1). The results from the present study confirms the results of Poduval *et al.,* (2015) in which the sugar content of 28 cashew apple genotypes were between 7.28 % - 12.53 %. Similar results have been reported by Attri, (2009) who reported total soluble sugar content of 10.00^{o} Brix when measuring the physicochemical properties of the Andaman cashew.

TABLE 1

Sugar content, pH, and weight of four cashew apple germplasms from Bole and Wenchi. Values are Mean ± S.E of three biological replicates of bulked apples.

Germplasm-location	Sugar content (%)	pH	Weight (g)
Brazil-Bole	$10.2^{b} \pm 0.20$	$4.2^{d} \pm 0.00$	$69.8^{d} \pm 3.00$
Brazil-Wenchi	$11.0^{bcd} \pm 0.40$	$4.0^{bc} \pm 0.00$	$53.2^{b} \pm 3.30$
Local-Bole	$12.5^{de} \pm 0.34$	$3.9^{a} \pm 0.042$	$37.7^{a} \pm 2.14$
Local-Wenchi	$11.6^{de} \pm 0.20$	$4.1^{cd} \pm 0.00$	$57.2^{bc} \pm 2.20$
Mozambique-Bole	$10.4^{bc} \pm 0.20$	$3.9^{a} \pm 0.00$	$63.1^{c} \pm 3.30$
Mozambique-Wenchi	$8.7^{a} \pm 0.30$	$4.0^{ab} \pm 0.00$	$55.6^{b} \pm 2.20$
Tanzania-Bole	$11.9^{de} \pm 1.07$	$4.3^{e} \pm 0.04$	$33.9^{a} \pm 2.61$
Tanzania-Wenchi	$11.2^{cd} \pm 0.29$	$4.3^{e} \pm 0.06$	$63.3^{c} \pm 2.90$
P-value	<.001*	<.001*	<.001*
$LSD_{(0.05)}$	0.64	0.05	3.83
CV%	29.9%	6.7%	36%

*= significant, CV= coefficient of variation, LSD= least significant difference, P-value= probability value

Generally, cashew apples from Bole had the highest sugar content as compared with that of Wenchi. This contradict the work of Lowor & Agyente-Badu, (2009) who from their study had the Forest savannah of which Wenchi belongs to recording higher sugar content in cashew apples as compared with the Northern savannah of which Bole is part. It must be noted that in the study of Lowor & Agyente-Badu (2009), the germplasms used were not considered separately compared to the current study and that might have contributed to the differences between the two studies.

In relation to pH (Table 1), it was seen that in the same germplasms but from different locations, as the sugar content increases, pH decreases and vice versa. In a study to evaluate the effects of pH on glucose measurements, Zhao *et al.,* (2018) reported that as glucose level increases, pH decreases and vice versa. However, a general corelation between sugar content and pH from both locations showed a weak positive correlation (Table 2). This may be attributed to the fact that the values of both parameters used for the analysis were bulked from all germplasms from both locations. However, these values had variations between each germplasm per location (Table 2) hence this might have given such a debatable result. Thus, it could be concluded that pH influences sugar accumulation in cashew apples.

Weather conditions affected sugar accumulation, pH, and weight of apples from both locations

Meteorological data obtained from both locations showed variations between the locations with regards to their temperature, rainfall, sunshine, and relative humidity (Fig. 1). Wenchi had increased amount of rainfall, rain days, and low relative humidity from February 2017 to April 2018. Bole had the highest maximum temperature screen reading while Wenchi had the lowest for the minimum temperature screen reading (Fig. 2). However, Bole had the highest amount of sunlight, and this might have led to the variations observed in the sugar content of the cashew apples (Elhaddad *et al.*, 2014). It has been reported that increase in rainfall causes higher levels of relative humidity (Umoh *et al.*, 2013) hence lower rate of evapotranspiration (Isikwue *et al.*, 2015). This influences the Cashew plant to retain high amount of moisture of which majority is later used for fruits development (Windt *et al.,* 2009). The high amount of water channelled by the plant into fruit development causes a higher fruit weight and sometimes a lower sugar content. Thus, this may be due to the highly directed amount of water present in the fruits diluting the amount of sugar produced by the plants in its fruits. This was observed in fruits from Wenchi which had increase weight, but lower sugar content as compared with fruits from Bole which showed the opposite trend. However, there was very weak negative correlation between sugar content and weight of the cashew apples from both locations (Table 2). An opposite of this model was seen in Brazil germplasms which had higher sugar content in Bole as compared to Wenchi. This might point to the fact that the Brazil germplasm is from a different continent (South America) as compared to the rest of the germplasm which are from Africa. Perhaps the parent plant might have developed some genetic traits which makes it react differently to the influence of the subjected ecological zones in this study. Alternately, the Brazil germplasm might have retained some traits of the original cashew ancestor (since cashew is believed to have originated from Brazil) making it react differently from the other germplasm which might have lost these traits. Cashew in Ghana start flowering from November to December hence fruiting normally starts from December to January (Food and Agriculture Organization of United Nations, 2012). Rainfall, rain days and its distribution have effect on the flowering and fruiting of tree crops hence both must be coherent. There was adequate rainfall and rain distribution (rain days) during the flowering and fruiting period in Wenchi as compared to Bole (Fig.1). An increase in temperature, relative humidity, and sunshine, dry or violent wind and a lower rainfall and rain days during the flowering and fruiting periods negatively affect cashew development through the abortion and drying of immature fruits and flowers (da Silva *et al*., 2018). Uneven and unexpected rainfall, rain days or rain distribution and photoperiods affects crop production through frequent fruits and flower abortion leading to about 5.5% reduction of annul crop yields (Idowu *et al*., 2011). Hence, good distribution of rainfall and rain days, an optimum temperature, relative humidity, and sunshine initiates early flowering and helps in flower and fruit development which leads to an increase in cashew yield. This was observed in cashew plants from Wenchi which had a higher apple weight as compared with fruits from Bole. A similar result has been reported by Balogoun *et al*., (2016). A correlation analysis of weather parameters showed that rainfall, rain days and relative humidity were negatively correlated with sunlight and temperature at both locations hence a good balance between these parameters can result in good yield confirming the above model (Supplementary data 1).

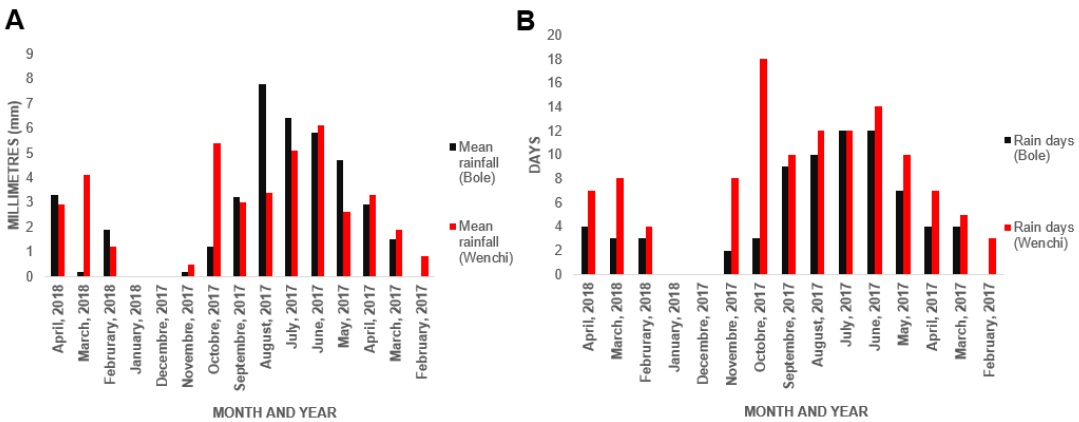

Fig. 1: Rainfall (A) and rainy days (B) for Wenchi and Bole from February 2017 – April 2018 farming season (source: Meteorological station, Wenchi and Cocoa Research Institute of Ghana-Bole substation, 2020).

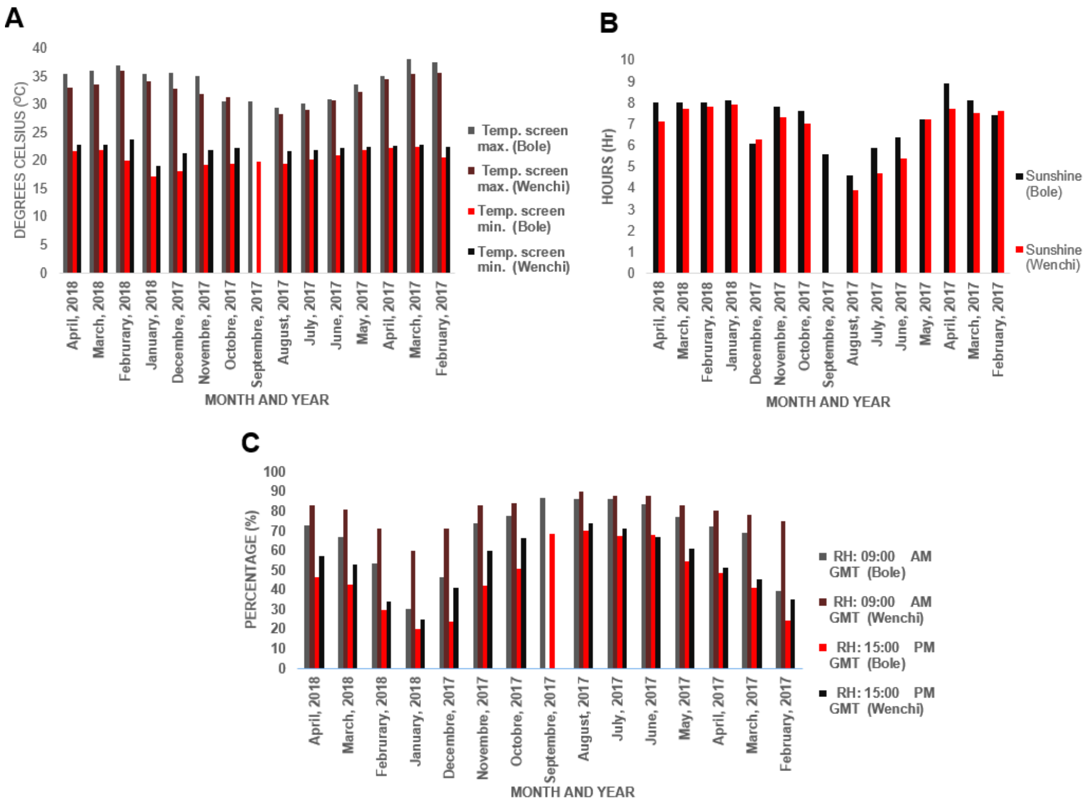

Fig.2: Temperature (A) sunshine (B) and relative humidity (C) for Wenchi and Bole from February 2017 – April 2018 farming season (source: Meteorological station in Wenchi and Cocoa Research Institute of Ghana-Bole substation, 2020).

TABLE 2

Correlation analysis of sugar content, pH, and weight of four cashew apple germplasms from two ecological zones.

	Sugar content	pH	Weight
Sugar content			
pH	0.115571		
Weight	-0.0554	0.013863	

Photosynthesis is mostly influenced by the amount of sunlight available to plants (Elhaddad *et al.*, 2014). Higher relative humidity in Wenchi causes it to experience a cloudy atmosphere in the morning as compared to Bole. This cloudy atmosphere prevents sunlight from getting to the cashew plants. Hence, a lower rate of photosynthesis (Elhaddad *et al.*, 2014) could have occurred in Wenchi in the morning while the opposite occurred in Bole. Moreover, the correlation analysis between relative humidity and sunlight at both locations was negatively correlated hence confirming this hypothesis (supplementary data 1).

Furthermore, photosynthesis in cashew plants mainly results in the production of its sugar. Therefore, cashew plants from Bole which experience a higher rate of photosynthesis have higher sugar content as compare with fruits from Wenchi. Cashew plants are C_3 plants and their stomata closes at night hence needs more exposure to sunlight during the day for efficient photosynthesis (Bareja, 2013). Exposure of sunlight has been reported to have an influence on the opening of the stomata in plants which determines the duration of photosynthesis of a plant in a day (Elhaddad *et al.*, 2014). Hence, the earlier the exposure of sunlight to the cashew plant in the morning, the longer the duration of photosynthesis of the plant in a day. The delay in exposure of cashew plants in Wenchi to sunlight per day might have led to fewer photosynthetic period in the plants as compared to those in Bole (Elhaddad *et al.*, 2014) (Fig. 2C). Therefore, sunshine had effect on the amount of sugar produced in the fruits. Also, temperature variations affect the activities of photosynthetic enzymes which reduce or increase the rate of photosynthesis (Yamori *et al.*, 2014; Markings, 2018). Lower temperature causes the reduction in both photosynthetic rate and the deterioration of the carbon budget in plants, a poor carbon budget results in lower sugar content and stem growth (Uehara *et al.,* 2009). Pilkington *et al*. (2015) reported that both an increase or decrease in temperature affects the plant sugar levels in *Arabidopsis thaliana* by either decreasing it or increasing the sugar levels, respectively. This may explain why fruits from Wenchi had lower sugar content than fruits from Bole (Table 1 and Fig. 2A). The sugar contents from same germplasms but different locations were not significantly different except for Mozambique which showed significant differences. These differences show how the same germplasm reacts to the same climatic conditions in relation to sugar production and metabolism (Castro *et al*., 2010).

To conclude, the germplasms responded differently in their sugar accumulation, pH and weight when exposed to different agro climatic conditions. Hence, germplasms and Agro climatic conditions have both positive and negative effects on the sugar content, pH, and weight of cashew apples. Cashew apple germplasms with high sugar content (Local-Bole) will be more economical for the alcoholic beverage producing companies and hence could be considered for the one district one factory programme to increase economic gains of farmers engage in Cashew production in

Ghana. Furthermore, the Tanzania germplasm from Wenchi has the potential to be considered for breeding with the local germplasm from Wenchi to get Cashew apples with appreciable sugar content and weight to increase economic gains of farmers engaged in this cash crop production.

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