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The properties of Sweet Sorghum Syrup Produced by Combined Vacuum Falling Film and Rotary Evaporation

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Abstract

The combination of Vacuum Falling Film Evaporator(FFE) and Rotary Evaporator (RE) was conducted in producing sweet sorghum syrup. The aim of this research was to evaluate the performance of single FFE and combined FFE-RE on sorghum syrup concentration. Single FFE was studied at the temperature of 70, 80, and 90°C. The best single FFE treatment was continued by RE at 60, 70, and 80°C. Sweet sorghum that were concentrated using single FFE(90°C) and combined FFE(90°C)-RE(80°C) had the highest Total Soluble Solid(TSS) of 44.2°Brix and 87.53°Brix, also the acceptable lightness(L*) of 30.13 and 25.83 respectively. That combined FFE-RE produced sorghum syrup had the highest overall Hedonic score 3.34 within the taste parameter value of 2.89; color of 3,75; aroma of 3,29; and texture of 3.42. It was also accomplished with the redness(a*) of -2.11, yellowness(b*) of 5.13, turbidity of 387.66 NTU, viscosity of 2036.67cP, and reducing sugar of 52.54%.

Keywords: brix, concentration, evaporation, lightness, liquid sugar, sorghum syrup, viscosity, sensory

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INTRODUCTION

Sorghum had high potential to be the raw material of sugar syrup because of its total sugar content (Andrzejewski & Eggleston, 2013). The previous sugar syrup generally was produced by diluting sugar crystals into water. This process take a high amount of energy and also cost for crystallization, centrifugation, and dilution process. In order to get high efficiency, it could by replaced by simple evaporation. This evaporation contributes to production of sugar that reduces the amount of energy used (Bantacut & Novitasari, 2016) and is waste by existing centrifugation (Bhatnagar *et al.*, 2016). Vacuum evaporation was recommended since it can reduce the boiling point of water. Therefore, the nutritional losses, browning reaction and taste reduction were minimized (Farahnaky *et al.*, 2016) and so in date syrup production. Falling film evaporation was evaluated as a good techniquue for that process (Koodaruth, 2015). At the previous work, it was used to evaporate sorghum juice with the optimum temperature of 83.71°C (Ali *et al.*, 2019). In addition, rotary vacuum evaporator has a high performance for food grade product. Briefly, it is necessary to do combination of falling film and rotary evaporator simultaneously.

RESEARCH METHOD

Materials

The main material used in this research was Sweet Sorghum (Sorghum bicolor (L.) Moench) harvested in BALITKABI Malang. It was mechanically extracted twice using local sugarcane milling machine to get sweet sorghum juice. Juice then was filtered twice with filter cloth 100 mesh and later was centrifuged (WINA Instruments) at the rotation speed of 720 rpm by 30 minutes. To get the clear juice, zeolite was added with concentration 3% w/w.

Experimental Design

Evaluation of FFE and combined FFE-RE was conducted by series. FFE was operated at 70, 80, and 90°C with flow rate of 5 mL/min and RE was operated at 60, 70, and 80°C and rotation speed of 70 rpm for 30 minutes.

Sorghum Syrup Production

Extraction

Extraction of sorghum with the length 30 cm of was done mechanically using commercial sugar cane press machine. In this study, 5 kg of sorghum was calculated to get the yield of extracts in units of volume/mass (mL/kg).

Filtration

Filtration of sorghum juice was done conventionally using a filter cloth with the size of ± 100 mesh. Filtration was helped by using vacuum pump. This juice then was characterized by the total suspended solids, turbidity, density, viscosity, volume, and mass.

Centrifugation

Amount of 500 mL of sorghum juice was poured into a centrifugation tube then a continuous centrifugation is carried out at a rotational speed 700 rpm with a duration of for 30 minutes.

Evaporation

There are two types of evaporation; single FFE and simultanious combination FFE and RE(IKA RV 10). FFE was operated at the flow rate of 5 mL/min and varying temperature. Otherwise, RE was operated at the rotation speed of 70 rpm and varying temperature, too.

Data Analysis

Determination of lightness was measured using color reader, Total Soluble Solid was measured using hand refractometer(Atago N-1E), and viscosity was measured using viscometer (elcometer 2300 RV). Data analysis was calculated using ANOVA(Analysis of Variance) with confidence interval off 95%. It was continued by Duncan's Multiple Range Test (DMRT) with 5% confidence interval.

RESULTS AND DISCUSSION

Single FFE Performance

Sweet sorghum juice was evaporated using single FFE with the flow rate of 5 mL/min. It was examined at temperature of 70, 80 and 90 °C. Evaporation could reduce the water content and also affected some parameter as shown in Table 1. Sorghum syrup treated by single FFE has TSS higher TSS than sugarcane. Lo *et al.* (2007) reported that sugarcane juice has TSS of 15°Brix and the concentrate of 30°Brix.

Table 1. Performance of single FFE

Temperature (°C)	TSS (°Brix)	Color parameters			Density(g/mL)
		L*	a*	b*	
70°C	39±1.57	30.33±0.61	-2.20±0.17	8.57±0.64	1.15±0.01
80°C	43.4±0.86	29.87±0.04	-2.47±0.05	7.90±0.08	1.17±0.01
90°C	44.2±0.05	30.13±0.09	-2.73±0.22	6.40±0.17	1.18±0.02

Table 1. showed that high temperature caused the higher TSS of syrup. It was because of the high number of heat of steam. The FFE with good heat transfer coefficient (Glover, 2004) promote better heat transferred to juice (Adib *et al.*, 2009). Hence, TSS increased extremely.

Combined FFE-RE Performance

Table 2. informed that second evaporation of sweet sorghum concentrate using RE significantly increased TSS. The highest TSS of 87.53°Brix was than the TSS of Algerian honey evaluated by Habati *et al.* (2017). TSS increase was followed by the increase of reducing sugar. TSS value that was higher than reducing sugar means there was still sucrose inside of syrup. TSS value increased according to reducing sugar since there was soluble sucrose (Crestani, 2018) and reducing sugar in sweet sorghum syrup recorded in TSS.

Table 2. Performance of combined FFE-RE

Temperature (°C)	TSS (°Brix)	Reducing sugar (%w/w)	Color parameters			Density(g/mL)
			L*	a*	b*	
60°C	45.00±0.01	34.46±0.01	31.62±0.99	-3.14±0.10	10.69±0.58	1.31±0.005
70°C	60.40±0.69	53.44±0.38	28.44±1.12	-2.42±0.30	7.85±0.27	1.41±0.012
80°C	87.53±0.50	52.54±0.01	25.82±0.58	-2.14±0.02	5.13±0.53	1.47±0.007

It was reported that by the RE evaporation for 15, 30, and 45 minutes promoted the reducing sugar content of 48.22, 52.54, and 53.24 respectively. A little increase of reducing sugar was promoted by little coversion of sucrose to reducing sugar. Simultanious FFE-RE by vacuum operation could lower the convertion of sugar that was mainly caused by hydrolisis reaction (Gehlawat, 2001) in a higher temperature process. Panpae *et al.* (2008) also mentioned that higher temperature let it aesier to degrade sucrose into invert sugar. This inverting sugar was unnecessary in food application.

Figure 1. showed that longer duration of evaporation caused the higher TSS since sucrose content increased. Within the increase of TSS, the lightness of sweet sorghum syrup slightly decreased. The increase of TSS value slightly affected the lightness of sweet sorghum syrup. Fig 1. informed that TSS changes of sweet sorghum syrup was higher than lightness changes. It has lower gradient (15.14) than gradient of TSS changes (70.6). Lightness reduction means the production of dark color that was mainly caused by the browning reaction. It is a kind of termal behavior of sugar (Lu *et al.*, 2017). With lower inversion of sucrose it can reduce the lightness decrease.

Sensory Evaluation Of Combined FFE-RE Sorghum Syrup

The evaporation of sweet sorghum juice using FFE-RE successfully produced acceptable sweet sorghum syrup. Sensory evaluation showed the most preferable product conducted by combined FFE(90°C)-RE(80°C). It was also supported by the highest value of overall acceptance and other parameters such as texture(viscosity), aroma and taste.

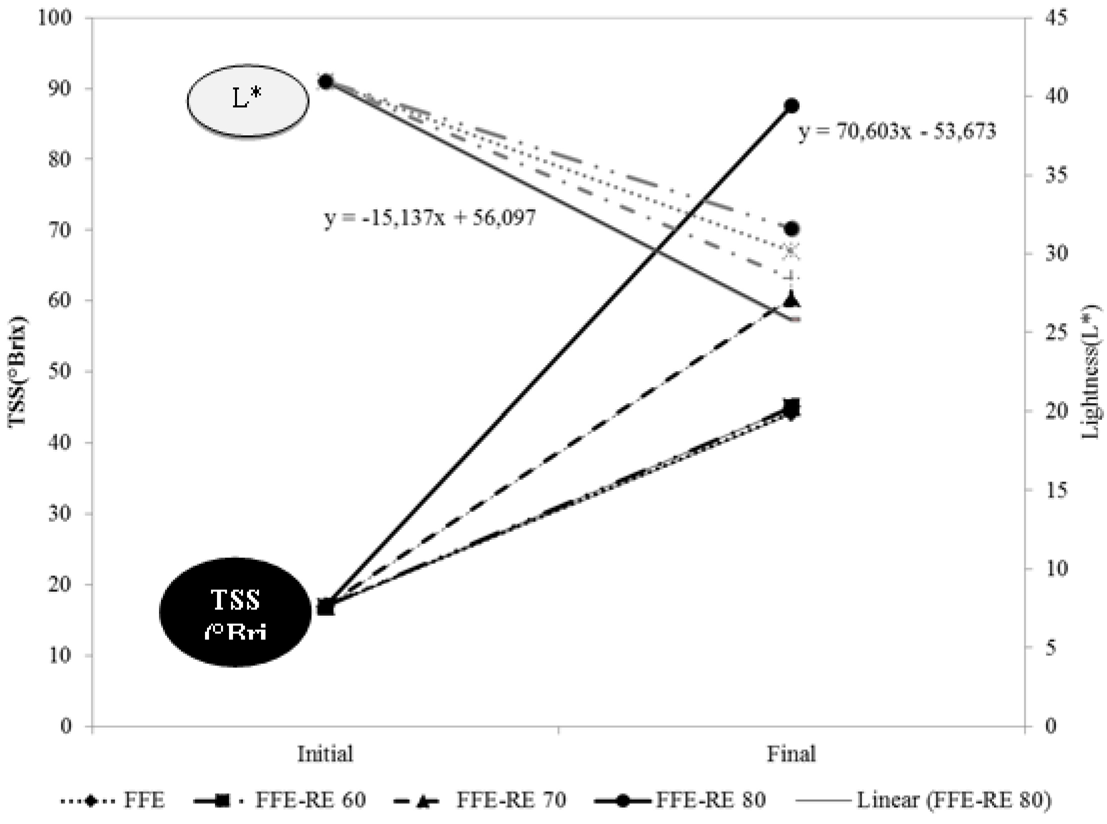

Figure 1. Degree of TSS and L*changes of sweet sorghum syrup

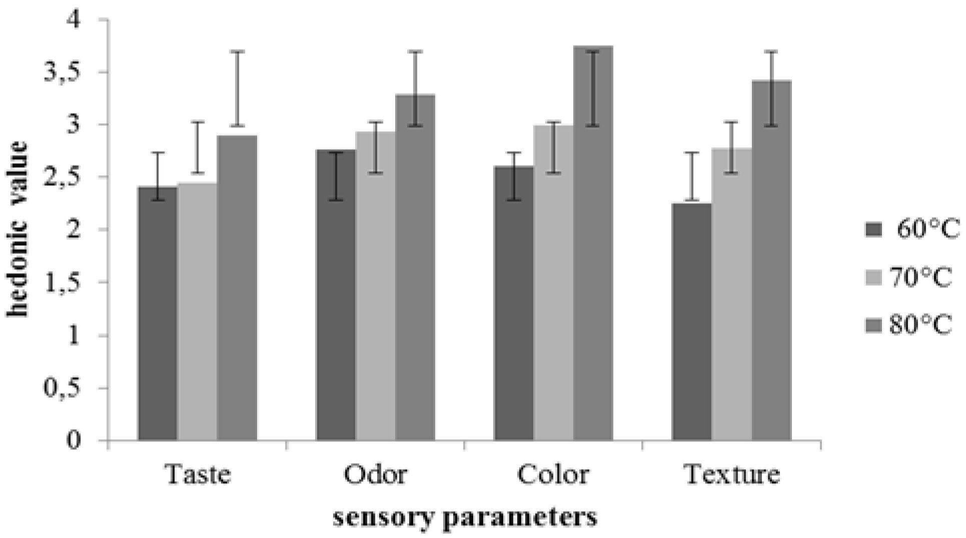

Figure 2. Sensory evaluation of combined FFE-RE sorghum syrup.

Figure 2. showed that color has the highest value. It was followed by texture, odor, and taste. This value was proved by combined FFE-RE. It was due to less browning reaction during evaporation. In contrast, taste has the lowest value because of the clorophyl content of sorghum. It was an antioxidant needed to increase health. However, sweet sorghum syrup taste need to be improved.

Properties of Sorghum Syrup

Combined FFE-RE successfully increased the TSS of sorghum syrup by five times. It was followed by the increase of reducing sugar by 2.4 times. The lower increase of reducing sugar than TSS indicate that the sucrose of sorghum syrup was stable during evaporation. It was also due to the low operation temperature of combined FFE-RE. The lower temperature could inhibit the inversion of sucrose to be glucose and fructose (Rackemann & Broadfoot, 2019).

Table 3. Properties of sorghum syrup

Parameters	Sample		
	Raw juice	FFE syrup	FFE-RE syrup
TSS (°Brix)	16,93 ± 0,83	44.2±0.05	87.53±0.50
Reducing sugar(%w/w)	20,87 ±1,30	25,14 ± 1,71	52.54±0.01
Viscosity (cP)	2.32±0.57	36 ± 0,00	593,67 ± 1.17
Turbidity (NTU)	876,67 ± 1,41	1290 ± 3,46	1192,333± 5.86
Color parameters:			
L*	40,96 ± 1,42	30.13±0.09	25.82±0.58
a*	-4,2 ± 0,35	-2.73±0.22	-2.14±0.02
b*	15,97 ± 1,05	6.40±0.17	5.13±0.53

Other physical properties such as viscosity and turbidity also increased but the lightness decreased by 0.63 times. The lightness decrease was still lower than TSS and other parameters. The increase of viscosity was responsible to the water losses by evaporation. It caused more concentration and interaction of solid components such as sucrose, glucose, fructose. It means higher viscosity was due to the high shear of solid particles in the lower volume of bulk sorghum syrup (Nefasa *et al.*, 2019).

Turbidity of sorghum syrup produced by single FFE was significantly higher that raw sorghum juice. It was caused by water losses during evaporation. However, sorghum syrup produced by combined FFE-RE had lower turbidity than single FFE. It was responsible to the higher temperature of RE in the sequences of FFE-RE. Quant *et al.* (2019) mentioned that the stability of aggregates in suspension could be disturbed by heating. Therefore, the turbidity of sorghum syrup produced by combined FFE-RE was lower than single FE.

CONCLUSION

The combination of FFE-RE evaporation could produce sweet sorghum syrup having high TSS value and slight dark color. This sorghum syrup has acceptable sensory value and it was verified with higher viscosity and lower turbidity.

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