Since 2001 ajfand AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
SCHOLARLY, PEER REVIEWED
Volume 24 No. 4
April 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2024; 24(4): 26038-26053 https://doi.org/10.18697/ajfand.129.24130

Date	Submitted	Accepted	Published
	22nd October 2023	28th February 2024	27th April 2024

WATER JET VACUUM COOLING SYSTEM FOR IMPROVING THE QUALITY OF MULTIFLORA HONEY FROM BEE *(Apis dorsata Fabricus)* IN INDONESIA

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ABSTRACT

Honey has great benefits to humans, both as medicine and food. It contains glucose, fructose and water in addition to small quantities of proteins, minerals, organic acids, and vitamins. Vacuum cooling is a rapid cooling technique based on the principle of evaporation, which lowers the boiling point of water based on the vacuum pressure inside a cooler room. A prototype vacuum-cooling jet water system was used to process the honey. Raw honey obtained from the forests of Riau was used in the present study. This study aimed to determine the effect of jet water vacuum cooling with variations in volume (V/V), capacity (12.5%, 25%, and 50%) on the quality of honey (*Apis dorsata Fabricus*) to accelerate the cooling process and preserve product quality. The cooling mechanical analysis parameters reviewed included the processing time and the lowest maximum pressure. The parameters of the quality of honey observed included moisture content, viscosity, density and total dissolved solids. As a result, the vacuum cooling process can suppress damage to the quality of honey owing to the heating process. At the cooling time and lowest maximum pressure value, the mechanical aspects of the water jet system vacuum cooling process showed the maximum results. The water contents of 12.5% (V/V), 25% (V/V) and 50% (V/V) filling were 13.69%, 12.89%, and 14.25%, respectively. The viscosities at 12.5% (V/V), 25% (V/V) and 50% (V/V) filling were 2.604 Pa.s, 2.355 Pa.s, and 1.644 Pa.s, respectively. Density with 12.5% (V/V), 25% (V/V) and 50% (V/V) filling were 1.52 g/cm^3, 1.53 g/cm^3 and 1.50 g/cm^3, respectively. Total dissolved solid values of honey with 12.5 % (V/V), 25 % (V/V), and 50 % (V/V) fillings were 78.16%, 78.16% and 77.66%, respectively. Water jet vacuum cooling with a 25% chamber volume capacity accelerates honey with the best total dissolved solids, density and moisture content. Vacuum cooling can be used to improve product quality, shorten handling time, extend product shelf life and improve security.

Key words: honey, pressure, vacuum cooling, density, moisture content, viscosity

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INTRODUCTION

The giant honeybee *Apis (Megapis) dorsata Fabricus* is widespread in Indonesia [1]. Honey is a great benefit to human beings both as medicine and food. It contains glucose, fructose, and water in addition to small quantities of proteins, minerals, organic acids and vitamins [2]. The honey production industry is a complex process. Each processing step is an answer to unique problems concerning the physicochemical and biological features of different types of honey [3].

The physicochemical parameters of honey can be employed for the evaluation of quality, such as density, viscosity, moisture content, total dissolved solids degree, color, sugar content, pH, multi-elemental composition, and antiradical activity of multifloral honeys from *Apis cerana cerana* [4, 5, 6, 7]. Honey is a supersaturated solution of sugar. Its unique combination of components makes honey a special addition to food supplements and the diet [8]. Honey is very sensitive to high temperatures because its mineral content is easily degraded. Heating honey above 70^{o}C causes the degradation of bioactive compounds that can affect honey quality [9] and can cause changes in the taste, color and granulation of honey [10] and the honey enzyme was denatured [11].

Vacuum cooling is a rapid cooling technique based on the principle of evaporation, which lowers the boiling point of water based on the vacuum pressure inside a cooler room. There three main pump designs: mechanical rotary pumps, steam jets and barometric condensers [12]. Vacuum cooling occurs because of the latent heat of food that evaporates because of the pressure vacuum (< 1 atm) [13]. Several previous studies that examined vacuum cooling have been used to cool liquid food materials, such as blueberry juice [14], honey [15], cooked meats, fishery products and ready meals [16]. This study aimed to determine the effect of jet water vacuum cooling with variations in volume capacity (12.5%, 25% and 50%) on the quality of honey, including the degree of total dissolved solids, viscosity, moisture content and density.

MATERIALS AND METHODS

In this study, a prototype vacuum-cooling jet water system was used to process honey (Figure 1). Some of the components of the vacuum cooling jet water system are cooling tubes, water jet pump-type vacuum pumps, insulator tubs for circulating cold water, heating stoves, control panel boxes, temperature sensors, hose lines and frames. A boiling three neck Pyrex (boiling flask) with a capacity of 1000 ml was used to determine the rise of material bubbles during the process. Other equipment included a stove mini portable, control panel, thermocouple K-type, manometer (Wiebrock, Taiwan), vacuum pump (Grundfos UPA 120, Taiwan),

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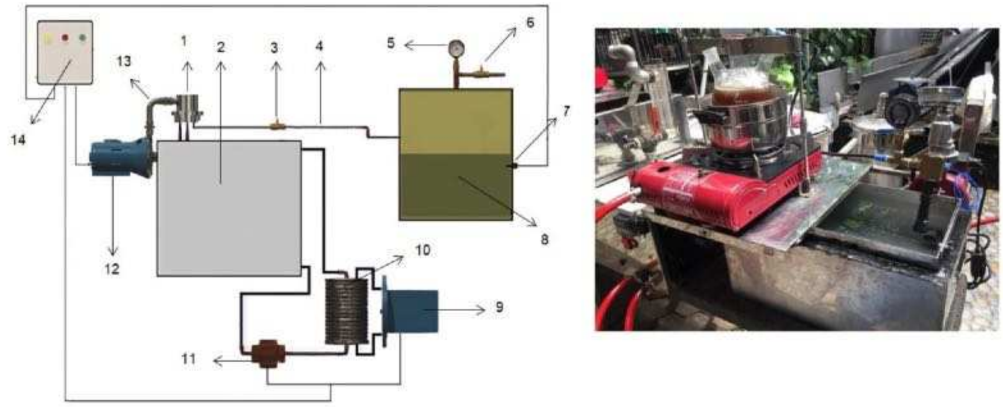
stopwatch, moisture analyzer (Shimadzu MOC 120H, Japan), and portable hand Brix refractometer 60-90%.

Bee type *Apis dorsata* forest honey was harvested in forest of Riau, Indonesia. The honey had the following specifications: moisture content,18.68%, viscosity, value 7.67 poise, density value 1.48 g/cm3, Total dissolved solids degree 74.6%.



Note:
1. Vacuum jet
2. Cold water bath
3. One-way valve
4. Vacuum valve
5. Vacuum meter
6. Air faucet
7. Temperature sensor
8. Vacuum tube
9. Dehumidifier cooling
10. Condensor cooler
11. Air pump circulation
12. Vacuum jet pump
13. Pump pipe to vacuum jet
14. Control panel box

Figure 1: Prototype and Schematic Diagram of Jet Water Vacuum Cooling System

Experiment

The material used in the research was raw multiflora honey obtained from the forests of Riau, Indonesia. Honey was stored in the closed storage drum. The vacuum cooling process was performed in triplicate with input variations of 12.5%, 25% and 50% V/V from the cooling tube used. In this case, the volume of the tube used was 1000 ml, the number of samples used was 125, 250 and 500 ml. The input variation treatments should not be more than ½ the volume of the evaporation chamber or 50% V/V because the honey foam rises as the pressure in the chamber decreases. During the vacuum-cooling process, each sample was pasteurized and conditioned at 63°C with a moisture content of <22% for 20-30 minutes using the double-jacket technique [17]. In the conventional cooling method, pasteurized honey is removed and placed in an open environment in a bottle used for pasteurization with the same sample amount as in the vacuum cooling process. The heat contained in honey is released into the surrounding environment, which has a lower temperature than honey, ranging from 63°C to 30°C. The study compared two cooling methods: vacuum cooling and conventional cooling, and the observations were the same.

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Analysis of the Cooling Process Time and Lowest Maximum Vacuum Pressure

The duration of the cooling process is an important indicator of the vacuum cooling process. The time was recorded using the GL200A midi Data Logger, if there was a change in temperature. Next, a graph of the relationship between the decrease in temperature and the cooling time was made. The observation of the cooling process time in the conventional cooling process was performed by recording every change in temperature.

The lowest maximum pressure value affected the temperature of the final material during cooling. The lower the vacuum pressure (< 1,013 bar), the lower the boiling point of water in vacuum. Providing a cold temperature of 8 ˚C in a water bath aims to increase the ability of the water-jet vacuum pump to vacuum the cooling tube. The lowest maximum vacuum pressure test was performed in triplicate for each treatment. The lowest maximum pressure was obtained when the temperature dropped to reach the final stage of the cooling process, which was 35 ˚C.

Analysis of the Moisture Content, Viscosity, Total Dissolved Solid and Density

The average moisture content of each sample after the heating and cooling processes was measured using a moisture analyzer (Shimadzu MOC 120H). The measurement serves to compare the percentage moisture content before and after processing.

Viscosity measurement was performed as previously described by Gomez- Diaz *et al*. [18]. Viscosity was measured using an NDJ-1S viscometer to determine changes in the viscosity of honey before the cooling process and after the cooling process for each sample in both vacuum cooling and conventional cooling. Spindle number 2 with a speed of 12 rpm was used to measure the viscosity of honey, because the poise value of honey was included in this value range. The density of the honey was measured before and after the cooling process. Density measurements were carried out using a 50 ml pycnometer. Density measurements were based on the method described by Oroian [19].

Analysis of Total dissolved solids

Total dissolved solids (system °Bx) is the sugar content in the aqueous solution. Total dissolved solids degrees were measured as described by Silva [20].

RESULTS AND DISCUSSION

Cooling Process Time

Vacuum cooling can be used to improve product quality, shorten handling time, extend product shelf life and improve security. Figure 2 shows that vacuum cooling

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with a volume capacity of 12.5% was 104 s and conventional cooling was 6870 s. The slowest cooling process time of vacuum cooling with a volume capacity of 50% was 410 s and conventional cooling was 17040 s. The cooling process time was observed when each honey sample at a temperature of 63 ˚C was decreased to 35 °C along with the vacuum pump run until the vacuum pressure was at its lowest maximum. The temperature of the environment during the experiment was 30–33 ˚C. The processing time for vacuum cooling can shorten the cooling process at an industrial scale. The cooling rate is directly affected by the reduction in air, which causes a relatively rapid decrease in temperature [21].

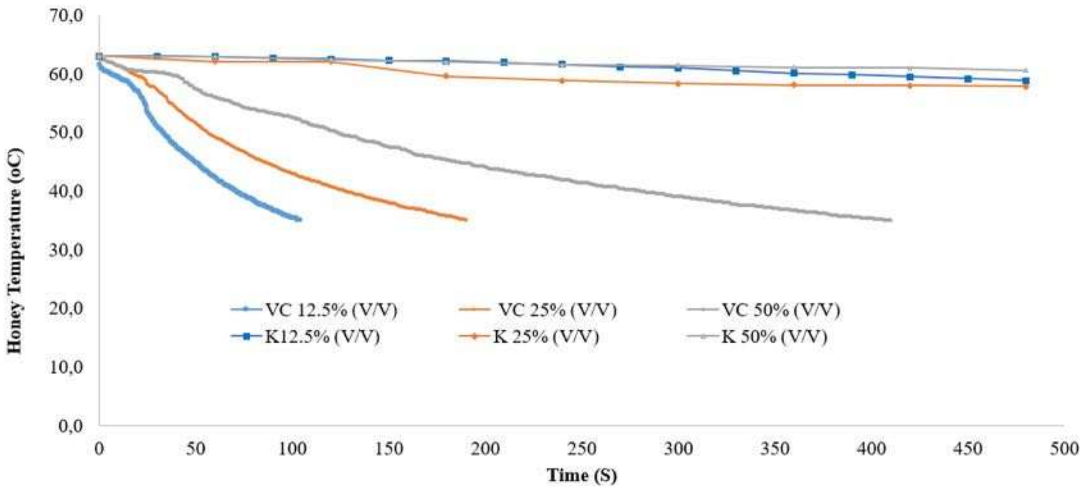

Figure 2: Honey Temperature Change with Vacuum Cooling (VC) and Conventional Cooling (K)

The Lowest Maximum Pressure of Jet Water Vacuum Cooling

The principle of vacuum cooling is based on the rapid evaporation of a part of the moisture content of the product under vacuum. Vacuum cooling has a specific structure that is based on different handling capacities and product characteristics [22]. During vacuum cooling, a large amount of vapor generated in the chamber is removed by the vacuum pump and/or through condensation when a vapor condenser is installed inside the chamber. Any food product with free water and whose structure will not be damaged by water removal can be vacuum-cooled [23]. The cold temperature in the water bath had a cooling effect on the air that was pulled out through a vacuum pump, which was then circulated in the cooling water bath. The water bath was cooled by adding ice water until it reached 8°C. The maximum energy efficiency for vacuum cooling in the honey cooling process is achieved at the lowest maximum pressure [24]. Based on preliminary research, the selected cold temperature of 8 °C in a water bath aims to increase the ability of the water jet vacuum pump to vacuum the cooling tube.

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The results of observing the change in pressure from the cooling process time to the lowest maximum pressure point for each treatment are shown in Figure 3**.** The lowest maximum vacuum pressure change rate was achieved using a vacuum pump during the cooling process for each treatment. The comparison shows that filling with 12.5% V/V is the fastest process for the pump to reach the lowest maximum pressure during the cooling process from 63 °C to 35 °C with a processing time of 104 s. Vacuum cooling with filling of 25%V/V and 50% V/V for the pump to reach the lowest maximum pressure during the cooling process from 63 °C to 35 °C was 190 and 410 s, respectively. During evaporation, heat is removed from the products. To maintain water evaporation, ambient pressure (chamber pressure) reduction must be ensured until the pressure that allows the attainment of a desired temperature is reached. The latent heat required for evaporation is supplied by the product itself, which reduces the sensible heat of the product and causes it to cool [25]. Houska [26] also presented the results of research on the mathematical model of the vacuum cooling process. The total pressure, *p,* in the space between the liquid and condenser is equal to the sum of the partial pressures of the non-condensable gas (air) and saturated vapor:

$$p = p_i(1-x) + p'x \qquad (1)$$

where p_i is the pressure of the noncondensable gas, p' is the saturated vapor pressure of water at temperature T, and x is the mass fraction of water vapor in the mixture.

Landfeld *et al.* [27] stated that the cooling rate d*T*/d*t* can be calculated on the basis of mass flow rate dm/dt. The mathematical model is based on the following kinetic equation:

$$\frac{dm}{dt} = kS(p - p'')$$

Measured mass loss data for the studied food samples during each vacuum cooling run were correlated as a function of the pressure differences for different time intervals. The proportionality constant in Eq. (2), *kS,* was then determined by linear regression. Houska *et al.* [28] then used mass loss calculations to determine the mass loss in pork during the vacuum cooling procedure.

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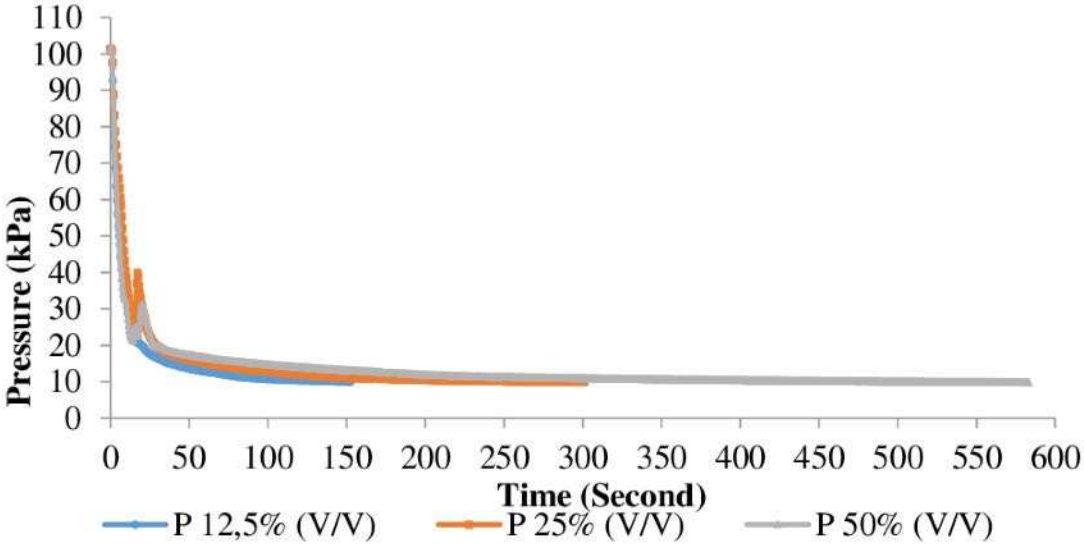

Figure 3: Lowest Maximum Pressure Rate Against Vacuum Cooling Process Time

Moisture Content

Moisture content is the water content of honey, and is expressed as a percentage by weight. Moisture content is the main parameter in honey storage after harvest. Therefore, honey that has just been harvested from the hive has a moisture content of more than 22%, which must be processed first and then reduced to below 22% to maintain the quality of honey. On the other hand, honey itself has hygroscopic properties, which means that honey easily absorbs water from the air or the surrounding environment. The research results in Table 1 show that the vacuum cooling process, apart from providing a cooling effect, is also an evaporation process at low temperatures.

The graph in Figure 4 shows that vacuum cooling helps water to evaporate low temperature during the pasteurization process. The moisture content of raw honey was 18.68% after pasteurization, and the water content dropped to 17.97%, which was affected by the lower environmental relative humidity (RH). After the vacuum-cooling process, the moisture content of the honey in each treatment decreased. In honey samples with 12.5% (V/V), 25% (V/V) and 50% (V/V) filling, the water contents were 13.7%, 12.9% and 14.25%, respectively. The reduction in water content of honey is caused by water evaporation when the pressure in the cooling tube drops below 1.01325 [29]. In conventional cooling, the moisture content was 17.97%, and honey did not experience a reduction in water content after the pasteurization process.

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Viscosity

The viscosity of honey is affected by its temperature and water content. Based on the graph in Fig. 4 and Table 1, the viscosity value changed in each process. The unit of viscosity used when collecting research data is Poise and then converted into SI units to Pascal second (Pa.s). The viscosity value of raw honey or raw material is 0.767 Pa.s, after the pasteurization process the viscosity value increases to 0.804 Pa.s. After vacuum cooling to 12.5% (V/V), 25% (V/V) and 50% (V/V), the viscosity value of honey increased to 2.604 Pa.s, 2.355 Pa.s and 1.644 Pa.s., respectively. In conventional cooling, the viscosity values for each filling of 12.5% (V/V), 25% (V/V) and 50% (V/V) were 0.836, 0.807 and 0.746 Pa.s, respectively. Viscosity is affected by the moisture content of honey; the lower the moisture content, the higher the viscosity [30]. In addition, viscosity is affected by the temperature of honey [31].

Density

The density is the ratio of the sample mass to the apparent volume and includes all internal pores up to the surface of the sample. Density is one of the parameters for observing whether the honey is of good or poor quality. Based on Figure 4 and Table 1, the density value of honey changes during the pasteurization process and conventional cooling in each treatment. In vacuum cooling, the density is higher than that in the conventional cooling process. This is because the moisture content of honey after vacuum cooling was lower than that after conventional cooling. According to Moniruzzaman *et al.* [32], honey that is dilute or has a high water content (> 22%) has a low density value.

Total Dissolved Solids

The degree of honey total dissolved solids was measured using a Brix refractometer with a scale of 60-92% to determine the change in total dissolved solids value in each treatment. The unit used to measure the total dissolved solids is the percentage (%). Figure 4 and Table 1 show that vacuum cooling can increase total dissolved solids value of honey. The initial total dissolved solid values of honey in the treatments with 12.5% (V/V), 25%(V/V) and 50% (V/V), after the pasteurization process were 75%, 75% and 74.7 %, respectively. Furthermore, the honey that was vacuum-cooled experienced an increase in the total dissolved solids percent value. The total dissolved solid values of honey in the 12.5 % (V/V), 25 % (V/V) and 50 % (V/V) filling treatments were 78.16%, 78.16% and 77. 66%, respectively. In conventional coolers, the total dissolved solid values of honey with 12.5 % (V/V), 25 % (V/V) and 50 % (V/V) fillings were 76%, 75.5% and 75. 5%, respectively. The total dissolved solids value of honey in vacuum cooling was higher than that in the conventional honey cooling process. The increase in the total dissolved solids value in the vacuum cooling process is supported by research

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SCHOLARLY, PEER REVIEWED
Volume 24 No. 4
April 2024
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

conducted by Monteiro *et al*. [33], which showed that the evaporation process can increase the total dissolved solids value. Honey with a high total dissolved solids value is preferred by consumers because of its distinctive sweet taste. The higher the total dissolved solids value in a liquid, the sweeter the taste of the liquid or food product [34].

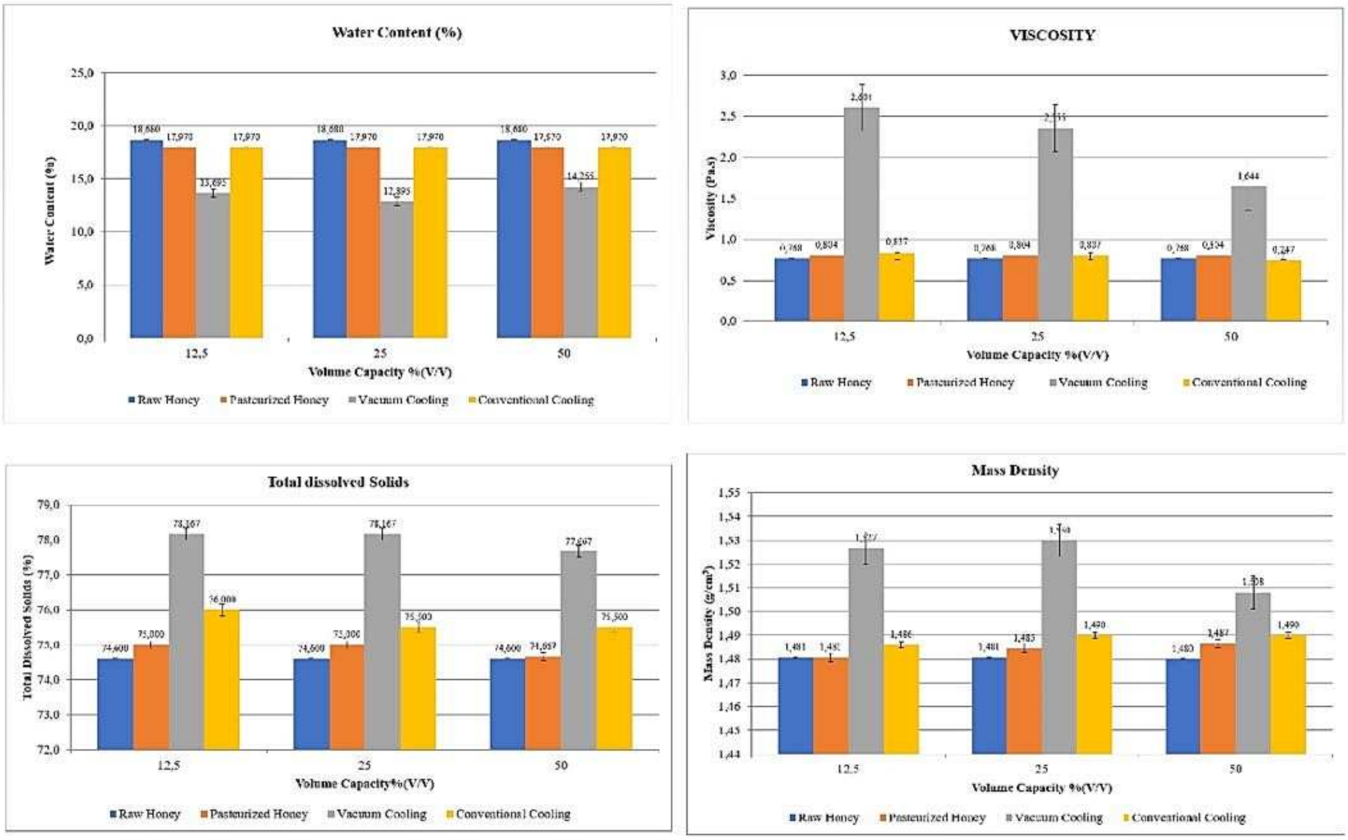

Figure 4: The Quality of Honey using Vacuum Cooling Jet Water and Conventional Cooling

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

Water jet vacuum cooling can speed up the cooling process and produce the lowest maximum pressure value to reduce the damage to honey quality. The best total dissolved solids degree, density and moisture content were obtained using water jet vacuum cooling with a volume capacity of 25 %.

The modification of pasteurization with water jet vacuum cooling system is required. Modification of vacuum cooling in the honey cooling process to increase the ability of vacuum pressure to reach the lowest boiling point of water. Both integrate modern pasteurization processes with vacuum cooling to improve the quality of honey.

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ACKNOWLEDGEMENTS

This research was supported and financed by the Indonesian Education Fund Management Institute (LPDP) through the RISPRO Funding Program.

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Table 1: The quality of honey using vacuum cooling jet water and conventional cooling

No.	Quality of Honey		Volume Capacity 12,5	25	50
1	Moisture Content (%)	Raw Honey	18.70 ± 0.03	18,69 ± 0.02	18,70 ± 0.01
		Pasteurized Honey	17.99 ± 0.02	17.97 ± 0.02	17.98 ± 0.01
		Vacuum Cooling	13.69 ± 0.27	12.89 ± 0.15	14.25 ± 0.24
		Conventional Cooling	17.98 ± 0.01	17.97 ± 0.01	17.97 ± 0.02
2	Viscosity (Pa.s)	Raw Honey	0.76 ± 0.01	0.76 ± 0.02	0.76 ± 0.01
		Pasteurized Honey	0.80 ± 0.01	0.80 ± 0.01	0.80 ± 0.01
		Vacuum Cooling	2.60 ± 0.10	2.35 ± 0.35	1.64 ± 0.01
		Conventional Cooling	0.83 ± 0.02	8.07 ± 0.01	0.74 ± 0.01
3	Density (g/cm^3)	Raw Honey	1.48 ± 0.01	1.48 ± 0.01	1.48 ± 0.01
		Pasteurized Honey	1.48 ± 0.01	1.48 ± 0.01	1.48 ± 0.01
		Vacuum Cooling	1.52 ± 0.01	1.53 ± 0.01	1.50 ± 0.01
		Conventional Cooling	1.486 ± 0.01	1.49 ± 0.01	1.49 ± 0.01
4	Total dissolved solids (%)	Raw Honey	74.5 ± 0.01	74.4 ± 0.01	74.4 ± 0.01
		Pasteurized Honey	75.0 ± 0.01	75.00 ± 0.01	74.66 ± 0.17
		Vacuum Cooling	78.16 ± 0.31	78.16 ± 0.24	77.66 ± 0.12
		Conventional Cooling	76.00 ± 0.01	75.50 ± 0.01	75.50 ± 0.01

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