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The Production of Red Wine from Black Jasmine Rice

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Abstract

This research was conducted by employing local black jasmine rice grown in Kampaengphet, Thailand as raw material for red wine production. The author firstly studied black jasmine rice fundamental information, black jasmine starch and liquid starch. The 2 levels suitable proportions of black jasmine starch and clean water screened from 6 levels were 1:3 and 1:5 (w/w) prior to TSS adjustment to 20 and 25 ^{o}Brix. The mixture was 10 days fermented with *Saccharomyces cerevisiae* yeast before conducting aging at 0-4 ^{o}C for 8 weeks. It was found the alcohol content of red wine produced from black jasmine rice was 12% after 10 days of fermentation and TSS was depleted to 7.5-9.25 ^{o}Brix as pH which insignificantly reduced from 3.17-3.12 to 3.46-3.62. Antioxidant activity comparison between before and after fermentation of black jasmine wine indicated 85.14-89.06% and reduced to 80.26-86.54% respectively, due to the fermentation and aging process which reduced average 27-41% of anthocyanin even though total phenolic was average 10-54% increased. Proportion between black jasmine rice starch and clean water contained different TSS has significantly effected to wine's sense quality at 95% of confidence level. Black jasmine rice wine produced from the black jasmine rice to clean water proportion of 1:5 with 25 ^{o}Brix TSS adjusted has obtained highest total hedonic score in the issues of color, clarity, sweetness, bitterness and significantly differed ($P<0.05$). All characteristics derived score were greater than 7 (moderate satisfied) except body characteristic.

Keywords: red wine, anthocyanin, antioxidant activity, phenolic compounds, fermentation

1. Introduction

Wines, the worldwide extensive popular alcoholic beverage that made from grape juice fermentation by yeasts which turn sugars in grape juice into alcohol (Beech & Timberlake, 1975). Wine aromas and tastes come from chemical composition of fermented grape juice. Sweet taste comes from sugars remained form fermentation, acid taste comes from tartaric acid, malic acid, lactic acid. Bitterness and astringency come from phenolic compounds anthocyanin and tannin in grape peels and seeds (Mulero et al., 2011; Jun et al., 2015).

Previous researches reported the suitability wine consumption is 250-300 ml/D (Yao et al., 2013). Wines help gaining in blood pressure, reduce heart disease risks, cancers, and coronary thrombosis as well as reduce blood sugar of diabetes patients due to the wine flavonoids such as quercetin, anthocyanin, flavonols, flavones, catechins and flavanones (Jackson, 2002a). These compounds are polyphenol which provide antioxidant activity, particularly in red wines which contain 1-2 g/L flavonoids meanwhile 0.2 g/L is found in white wine (Ichikawa et al., 2001). Moreover, histamine presented in wines can deplete body stress and migraines (Jackson, 2002b).

The 7-15% range of alcohol content in wines is insufficient for microbial growth prevention. But a microbial growth inhibition activity depends on wine compositions, particularly phenol volume and anthocyanin extraction process during fermentation period which affect to the reduction of virus, protozoa and bacteria growth. Phenol and tannin inhibit the growth of *Escherichia* spp. *Shigella* spp., *Proteus* spp. and *Vibrio s*pp., which are the causes of dysentery and diarrhea. Besides, they also inhibit growth of virus strains such as Polioviruses, Rhinoviruses and Coronaviruses reside in trachea and intestine.

Wine production form rice requires starch degradation and transformation to sugars by enzyme. Selection of raw materials used in winemaking, acidity would be considered because each kind of raw material has different acidity. The suitable pH for wines ranged in 3.3-4.5 and the selected raw materials should be consisted of suitable nutrients for yeast growth and enrichment is required in case of insufficient nutrient.

The primary survey of black jasmine rice grown in Kampaengphet province reported the cultivating rice is screened and developed until reached the product of fine, long and purple grain rice. Typically, cooked rice is soft, sticky and fragrance. Importantly, rice is consisted of 12.5% of protein, 70% of carbohydrate and 16% amylose as well as contains iron, zinc, copper and potassium. Furthermore, black jasmine rice contains high anti-oxidation substrates 293 μmol/g and the purple aril is consisted of anthocyanin, proanthocyanidin, bioflavonoids and vitamin-E which are antioxidants. Black jasmine rice has natural pigment that is suitable for food and beverage processing, especially bright red pigment required in wine production.

This research aimed to study in wine processing using black jasmine rice. Due to the pigment and taste of black jasmine rice wine probably act as antioxidant source and response requirements of current consumers, whom alert in wellness interest. Black jasmine rice wine also increases black jasmine values, produces additional incomes for local peoples and reduces the number of imported wines from foreign countries. There are 4 main objectives of this study: (1) To study in fundamental information of black jasmine rice, black jasmine rice starch and liquid starch which were used in red wine fermentation process. (2) To obtain suitable proportion of black jasmine rice starch to clean water and TSS for laboratory level red wine fermentation using black jasmine rice. (3) To study in the changes of TSS, alcohol content and pH during fermentation process of red wine production using black jasmine rice. (4) To compare the quantity changes of anthocyanin, phenolic, reducing sugar and antioxidant activity changes of black jasmine rice red wine between before and after fermentation process.

2. Method

The experimental material: black jasmine rice was collected from Nakornchum district, Kamphaengphet province, alpha-amylase enzyme & gluco-amylase enzyme purchased from Lansing Co., Ltd. Bangkok, Thailand. Studied in fundamental information black jasmine rice starch and liquid starch, which each performs as wine fermentation raw materials was conducted by using colorimeter for quality inspection. The measured values were reported as L*, a* and b*. The moisture analyzer was employed for moisture content measurement, measured TSS by hand refractometer and pH values were measured by pH meter.

Screened for suitable black jasmine rice syrup by weighted black jasmine rice starch and clean water in 6 different proportions: 1:1, 1:2, 1:3, 1:4, 1:5 and 1:6 (w/w). The homogenous mixture was degraded by enzyme and measured color value using colorimeter L*, a*, b*. The TSS was also measured and the obtained color was compared to 2 brands commercial wine such as Full Moon Wine Cooler and Spy Wine Cooler (Ortiz et al., 2013). Two proportions which produced black jasmine syrup color which were closest to commercial wine color were selected (Hayasaka et al., 2005).

The red wine production was conducted by mixing black jasmine rice to clean water as suitable ratio, adjusted pH to 3.5-4.5 and added alpha-amylase enzyme (Van & Pretorius, 2000). The mixture was 90 minutes heated up to 100 ^{o}C and cooled down by room temperature (25 ^{o}C). Measured sweetness value and added gluco-amylase enzyme followed by DAP, mixed and covered for 24 hours. Afterwards, added *S. cerevisiae* (2 g/L) and allowed fermentation progress. The wine samples were collected at 0, 1, 2, 3, 4, 6, 8 and 10 days of fermentation. The fermentation process was terminated by adding potassium metabisulfite and wine sediments was isolated using bentonite. Clarified wine was transferred to new tank and aging for 8 weeks at 4 ^{o}C prior to various tests and packed in wine glass bottle (Ueda et al., 1990; Ueki et al., 1991).

Inspected the quality of red wine made from black jasmine rice before fermentation process. The 4 treatment black jasmine rice syrup samples were measured for chemical values such as TSS by hand refractometer, pH by pH meter, amount of reducing sugar by Somogyi-Nelson method, antioxidant activity by DPPH radical scavenging assay, amount of anthocyanin by pH-differential spectrophotometry (Fuleki & Francis, 1968), amount of total phenolic by Folin-Ciocalteu colorimetric and color value by colorimeter (reported as L*, a* and b*).

Conducted the quality value measurement during 10 days of fermentation. After added yeast to 4 treatments quality adjustment of black jasmine rice syrup, then stored at room temperature to allow fermentation progress. At day 0, 1, 2, 3, 4, 6, 8 and 10, the samples were randomly selected from each fermenter for chemical analysis. The samples were analyzed for TSS by using hand refractometer, pH by pH meter and alcohol content by Ebuliometer.

Measured the quality values after 8 weeks of black jasmine rice red wine fermentation. These quality tests were conducted: color value by colorimeter (reported as L*, a* and b*); TSS by hand refractometer; alcohol content by ebuliometer; pH by pH meter; amount of reducing sugar by Somogyi-Nelson method; antioxidant activity by DPPH radical scavenging assay and; amount of anthocyanin by pH-differential spectrophotometry. The red wine measured color value using colorimeter and sensory evaluation by wine tasting in controlled sensory room with questionair 9-points hedonic scale test by 50 trained volunteers (Kwak et al., 2015).

3. Results and Discussion

3.1 Fundamental Information of Black Jasmine Rice and Products

The fundamental information of black jasmine rice which was used as raw material for syrup preparation in red wine fermentation process was shown in Table 1. The moisture content of black jasmine rice was 12.48±0.43% equivalent to the criteria of normal rice standard. The color values expressed as L*, a* and b* were 40.87±0.21, 11.58±0.13 and 1.28±0.24, respectively. The results indicated black jasmine rice grains have L* value inclined to black, a* value of dark red and b* value of slight yellow. From all color values, it suggested the color of black jasmine rice was dark red inclined to black.

The data in Table 1 illustrated 9.16±0.64 of black jasmine rice moisture content, equivalent to standard level. The starch color values expressed in L*, a* and b* were 56.44±0.31, 5.85±0.24 and -7.03±0.68, respectively. These values were interpreted as L* of black jasmine rice was inclined to light grey due to the milling made the body of grain distributed and led to color changes. a* value indicated reduced dark red compared to black jasmine rice grains and b* value implied light blue color due to grain surface was milled and mixed in starch. From all color values, it suggested the color of black jasmine rice was grey and light blue.

It was found in Table 1 that liquid starch has 3.00±0.50 ^{o}Brix of TSS, pH of 7.83±0.09 which were not suitable for the growth of yeast employed in wine fermentation process (suitable pH was ranged in 3.5-4.5). It was seen that pH of liquid starch was neutral. Moreover, the moisture content of liquid starch was 84.48±0.53%, similarly to 84.12- 84.96% of fruit juice moisture content. The black jasmine rice liquid starch L*, a* and b* values were 30.20±1.25, 13.42±0.48 and- 5.55±0.21, respectively. These values indicated the characteristic of black jasmine rice liquid starch was very dark red-purple. In the issue of red wine production quality, it must be adjusted for suitability by enzyme degradation which transforms starch into sugar before yeast fermentation (Reddy & Salunkhe, 1980).

Table 1. The characteristics of black jasmine rice and products

Characteristics	Black jasmine rice	Black jasmine starch	Black jasmine liquid
Color			
L*	40.87±0.21	56.44±0.31	30.20±1.25
a*	11.58±0.13	5.85±0.24	13.42±0.48
b*	1.28±0.24	-7.03±0.68	-5.55±0.21
Moisture content (%wet basis)	12.48±0.43	9.16±0.64	84.48±0.53
TSS (^{o}Brix)	-	-	3.00±0.50
pH	-	-	7.83±0.09

3.2 The Suitable Ratio for Black Jasmine Rice Starch and Water

In the screening experiment to evaluate the suitable ratio of black jasmine rice to clean water in syrup production, there were 6 levels of ratios between black jasmine rice and clean water for syrup preparation: 1:1, 1:2, 1:3, 1:4, 1:5 and 1:6 (w/w). The mixtures were measured for color values and compared with 2 commercial wines: Full Moon and Spy Red. The results of comparison were shown in Table 2.

The results of comparison between black jasmine rice syrup colors at each ratio illustrated the syrup produced from ratio 1:5 has closest color to Full Moon wine which provided 37.19, 28.87, 6.09 for the color parameters L*, a* and b*, respectively, particularly in L* and b*. Spy Red wine provided 31.24, 28.39 and 3.02 for L*, a* and b*, respectively, and syrup at ratio 1:3 produced closest L* (33.57), syrup at ratio 1:4 produced closest b* (3.73), but there was no significant differences in a* between both two ratios (31.29-31.46). It indicated that syrup at ratio 1:4 was bright red while syrup at ratio 1:3 was dark red or purple-red which is well color aspect for red wine, then syrup at ratio 1:3 was selected. The syrup at ratio 1:5 also was selected because it produced suitable TSS (20.00 – 25.00 ^{o}Brix). These two syrup ratio would be employed for next experiments.

Table 2. The characteristics of the ratios between black jasmine rice starch with water

The ratios (rice:water)	Color			TSS (°Brix)
	L*	a*	b*	
1:1	26.63±0.12	26.12±1.18	-9.86±0.34	30.00+0.50
1:2	29.98±1.18	30.19±0.63	-4.03±1.00	28.00+0.50
1:3	33.57±1.04	31.29±0.79	1.54±0.37	25.00+0.50
1:4	35.75±0.73	31.46±1.00	3.73±0.72	23.00+0.50
1:5	39.37±0.43	31.66±1.20	6.52±0.54	20.00+0.50
1:6	42.95±0.70	32.66±0.74	6.90±0.54	15.00+0.50
Full moon	37.19±0.43	28.87±0.39	6.09±0.21	-
Spy red	31.24±1.03	28.39±0.55	3.02±0.33	-

3.3 The Changes of TSS, Alcohol Content and pH During Fermentation Process

Determination of the suitable ratio between black jasmine rice and clean water in syrup production for red wine fermentation was conducted by 2×2 Factorial Experiment in CRD experiment design. There were two different ratios between starch and clean water: 1:3 and 1:5 and two different TSS levels of ferment liquid: 20 and 25 ^{o}Brix which acted as study factors. 4 treatments used in experiment and the black jasmine rice syrups were measured for pH, alcohol content, TSS, antioxidant activity, amount of anthocyanin and total phenolic, before and after fermentation. The experiment results were discussed in next sections.

Black jasmine rice syrup from each fermenter was analyzed for chemical quality in 0, 1, 2, 3, 4, 6, 8 and 10 days after fermentation. The results were shown in Figures 1-3.

Figure 1 illustrated the results of alcohol content changes (%) during black jasmine rice fermentation. It was found the alcohol content was significantly increased ($P<0.05$) during 10 days of fermentation due to the sugars were transformed into alcohol with assistance of *Saccharomyces cerevisiae* in anaerobic condition as the chemical reaction shown below:

$$C_6H_{12}O_6\text{------} > 2C_2H_5OH + 2CO_2 + \text{energy}$$

It was reported that alcohol has affected to yeast activity (Moreno-Arribas & Polo, 2009). The high alcohol content may cause decomposition or change of yeast cell membranes. Yeast was able to produce 2.43-2.73% alcohol content in day 1st of fermentation, increased to 5.29-6.69% in day 3rd and increased to 9.50-10.78% in day 6th. For day 8-10th of fermentation, the treatment 2 produced constantly alcohol content ranged in 11.25-12.18% ($P<0.05$), meanwhile the alcohol contents of treatment 1, 3 and 4 were significantly increased.

However, after 10 days of fermentation was terminated, all treatments produced 12% alcohol content which means there no effect from different ratios and TSS adjustment to the last period of fermentation (Schmidtke et al., 2012).

From TSS in black jasmine rice syrup during fermentation analysis results, TSS values of every treatment of syrup which most consisted of sugars from enzyme degradation were reduced in same approach (Figure 2). Normally, yeasts take 95% of sugar to be turned into alcohol and CO_2 and the 5% remained sugars will be taken for yeasts growth, produce energy and other benefits.

After added initial yeast, there was a short time for adaptation which observed from the significant reduction of TSS in every treatment at 95% of confidence value since 1st day of fermentation. In treatment 1 and 3, TSS reduced from 20 to 14.0-15.5 ^{o}Brix and reduced from 25 to 14.7-15.4 ^{o}Brix for treatment 2 and 4.

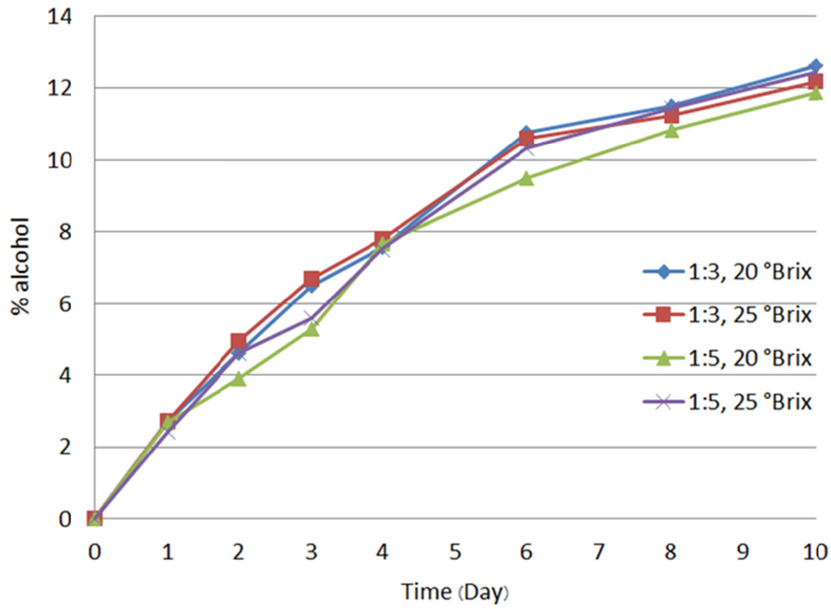

Figure 1. Changes in alcohol during fermented at 0, 1, 2, 3, 4, 6, 8 and 10 days

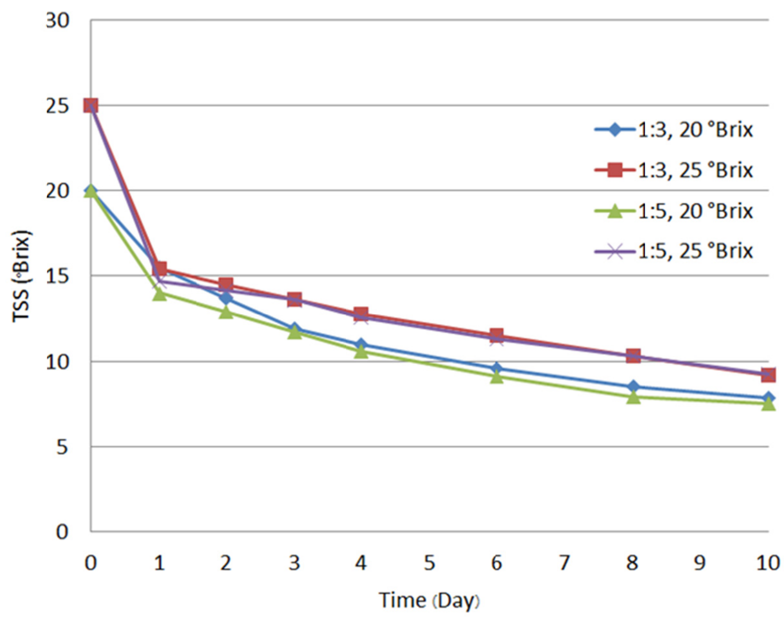

Figure 2. Changes in Total soluble solid (TSS) during fermented at 0, 1, 2, 3, 4, 6, 8 and 10 days

Afterwards, TSS of treatment 1 was continually reduced and approached constant at 7.9-9.6 ^{o}Brix in day 6th – 10th while there's no change TSS for treatment 3 and 4 (9.2-10.3 ^{o}Brix) in day 8th-10th. But for treatment 2, the TSS was significantly reduced in all 10 days. It was observed in the last day of fermentation, TSS of treatment 1 and 3 was similar (7.85±0.35 and 7.50±0.42 ^{o}Brix) as treatment 2 and 4 which also produced similar TSS (9.15±0.21 and 9.25±0.35 ^{o}Brix, respectively).

Figure 3 illustrated pH changes during black jasmine rice syrup fermentation. It was found pH reduced during fermentation in every treatment due to CO_2 was produced together with alcohol in fermentation, it can react with water and transform to carbonic acid which is acid medium. Before fermentation (day 0), black jasmine rice syrup of 4 treatments pH were 3.71 but in the last day (day 10) the pH of treatment 1 and 2 syrup which prepared from 1:3 syrup ratio were similar (3.60 and 3.62) and the pH of treatment 3 and 4 syrup which prepared from 1:5 syrup ratio were lower (3.46 and 3.48). The yielded acid affected to wine taste and played role of preventing wine from rotten because of bacterial activity during fermentation, aging and store.

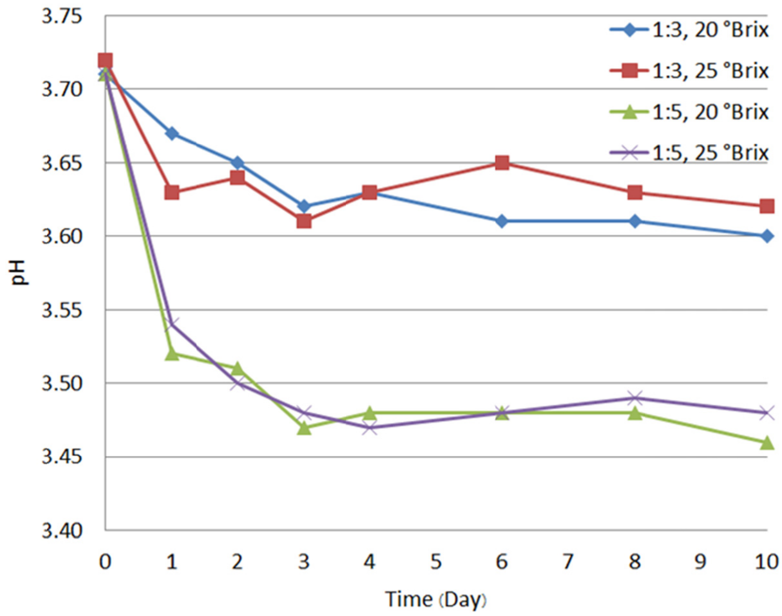

Figure 3. Changes in pH during fermented at 0, 1, 2, 3, 4, 6, 8 and 10 days

3.4 The Changes of Chemical Characteristics before and after Fermentation

3.4.1 Amount of Anthocyanin and Total Phenolic

Analysis of anthocyanin using pH-differential spectrophotometry method and total phenolic using Folin-Ciocalteu colorimetric method with employed Gallic acid as standard solution in black jasmine rice red wine illustrated results in Table 3.

The anthocyanin analysis in black jasmine rice syrup used in fermentation indicated average amount of anthocyanin were 350.68 and 673.47 mg/L for 1:3 and 1:5 syrup ratio before degraded by enzyme, respectively. After enzyme degradation, amount of anthocyanin was ranged in 466.57-827.26 mg/L.

Compared to black jasmine rice wine before fermentation, amount of anthocyanin after fermentation and aging was significantly reduced $P \leq 0.05$) in each treatment. The most of anthocyanin reduction was found in treatment 1 by reduced from 827.26 mg/L to 485.60 mg/L (41% of reduction).

Treatment 3 yielded lowest anthocyanin reduction, reduced from 491.11 mg/L to 357.36 mg/L (27%). The anthocyanin reduction comes from the influence of wine precipitation from bentonite, some parts of anthocyanin was lost with sediments as well as the result form anthocyanin bleaching. Moreover, anthocyanin was easily destroyed by high temperature, high sugar concentration, unsuitable pH and aerobic state. These factors accelerate anthocyanin degradation rate.

Table 3. The effect of the ratios between rice starch with water and TSS on the concentration of anthocyanin and total phenolic

Treatments	Anthocyanin content (mg/L)		Total phenolic (g/100mL)	
	Before	After	Before	After
1:3, 20 °brix	827.26 ± 70.38^{aA}	485.60 ± 45.34^{aB}	0.20 ± 0.02^{aB}	0.22 ± 0.01^{aA}
1:3, 25 °brix	726.90 ± 95.17^{aA}	517.33 ± 34.01^{aB}	0.22 ± 0.04^{aB}	0.26 ± 0.03^{aA}
1:5, 20 °brix	491.11 ± 42.27^{bA}	357.36 ± 12.75^{bB}	0.11 ± 0.10^{bB}	0.17 ± 0.00^{bA}
1:5, 25 °brix	466.57 ± 12.75^{bA}	315.11 ± 16.77^{bB}	0.12 ± 0.00^{bB}	0.17 ± 0.01^{bA}

a-b: Different superscript letters within a column denote significant differences ($p<0.05$).

A-B: Different superscript letters within a row denote significant differences ($p<0.05$).

For the comparison of 4 treatments anthocyanin, it was found in before fermentation that average anthocyanin in black jasmine rice wine prepared using 1:3 syrup ratio (treatment 1 and 2, 726.90-827.26 mg/L) was significantly greater than 1:5 syrup ratio (treatment 3 and 4, 466.57-491.11 mg/L) due to higher concentration. The results after fermentation were unidirectional which amount of anthocyanin of treatment 1 and 2 was still greater than treatment 3 and 4 (517.33-485.60 mg/L and 315.11-357.36 mg/L respectively).

For amount of total phenolic in black jasmine rice syrup before enzyme degradation in fermentation process, the 1:3 and 1:5 syrup ratio yielded average total phenolic as 0.14 and 0.21 g/100 mL, respectively. The constant amount of total phenolic ranged in 0.11-0.22 g/100 mL was found after enzyme degradation (Jun et al., 2015).

After fermentation, black jasmine rice wine yielded significantly greater total phenolic compared to before fermentation $P \leq 0.05$). The greatest increment of total phenolic was found in treatment 3 (0.11 g/100 mL to 0.17 g/100 mL, 54%) followed by treatment 4 which total phenolic increased from 0.12 g/100 mL to 0.17 g/100 mL (42%) (Tang et al., 2015).

Treatment 1 and 2 yielded lowest increment of total phenolic as 10% and 18% respectively. The increased total phenolic come from the state before fermentation, analysis of black jasmine rice syrup during fermentation and the mixing of black jasmine rice fractions remained from enzyme degradation in fermenter and phenolic compounds remained in surface and body of rice grain were additionally extracted. Moreover, ethanol content which increased during yeast fermentation also improved phenolic extraction efficiency. Polyphenol typically found in surface and grain and would be dissolved by alcohol during fermentation (Teramoto et al., 1994).

Comparison between total phenolic of 4 treatments indicated black jasmine rice prepared from 1:3 syrup ratio yielded significantly greater than 1:5 ratio in state of before fermentation (0.20-0.22 g/100 mL compared to 0.11-0.12 g/100 mL). This was unidirectional in state of after fermentation, treatment 1 and 2 yielded higher total phenolic than treatment 3 and 4 (0.17 g/100 mL compared to 0.22-0.26 g/100 mL).

3.4.2 Antioxidant Activity

From the analysis of antioxidant in black jasmine rice syrup before enzyme degradation, it was found 1:3 and 1:5 syrup ratio produced average DHHP as 86.21% and 89.31%, respectively. After adjusted by enzyme degradation, DPPH was ranged in 85.14-89.06% (Kim et al., 2014).

From the data shown in Table 4, the comparison of antioxidant activity of black jasmine rice wine between before and after fermentation implied no significant differences ($P>0.05$) although overall antioxidant activity was reduced after fermentation and ranged in 80.26-86.54% particularly in treatment 1 which antioxidant activity was reduced from 84.76% to 80.26% due to amount of anthocyanin in black jasmine rice wine was reduced after fermentation, aging and clarification (Min et al., 2011; Jiao et al., 2014). The wine antioxidant activity comes from polyphenols such as phenolic compounds which are high amount in black jasmine rice surface, especially free anthocyanin which performs higher antioxidant activity than the substrates in tannins-polysaccharides-tannins salts, very condensed tannins, procyanidins & catechins and tannin-anthocyanin complexes group (Ichikawa et al., 2001). The anthocyanin lost leads to reduction of antioxidant activity in black jasmine rice wine. Besides, there is some report identified the antioxidant activity could be reduced form adding potassium metabisulfite in ferment liquid preparation process affect to the antioxidant activity compared to the wine which prepared from boiling (Koguchi et al., 2009; Liu et al., 2010; He et al., 2014).

Table 4. The effect of the ratios between rice starch with water and TSS on the antioxidant activity

Treatments	DPPH % inhibition		DPPH (mg VCEAC/100 mL)	
	Before	After	Before	After
1:3, 20 °brix	84.76 ± 0.41^{bA}	80.26 ± 1.75^{cB}	425.04 ± 3.39^{bA}	387.66 ± 14.55^{cB}
1:3, 25 °brix	85.14 ± 0.23^{bA}	81.05 ± 2.39^{bcA}	428.13 ± 1.94^{bA}	394.18 ± 19.88^{cB}
1:5, 20 °brix	89.06 ± 2.04^{aA}	86.54 ± 0.12^{aA}	460.71 ± 16.97^{aA}	439.18 ± 0.69^{aA}
1:5, 25 °brix	88.69 ± 0.81^{aA}	84.55 ± 0.58^{abA}	457.62 ± 6.78^{aA}	423.32 ± 4.85^{bB}

a-c: Different superscript letters within a column denote significant differences ($p<0.05$).

A-B: Different superscript letters within a row denote significant differences ($p<0.05$).

VCEAC: Vitamin C equivalent antioxidant capacity.

The DPPH antioxidant activity was measured in the unit of radical scavenging activity percentage and the measured values were employed for Vitamin C equivalent antioxidant capacity calculation in 100 ml wine sample (mg VCEAC/100 ml) as shown in Table 4. It was found treatment 3 and 4 provided highest DPPH antioxidant activity as 439.18 and 423.32 mg VCEAC/100 ml (Goufo & Trindade, 2014).

3.4.3 Total Reducing Sugar

Total reducing sugar analysis was conducted by Somogyi-Nelson method which analyzed black jasmine rice syrup used in fermentation before enzyme degradation. The average percentage values were 2.12% and 1.35% for 1:3 and 1:5 syrup ratios respectively. Total reducing sugar was trivially increased, ranged in 2.16-4.11% after degraded by enzyme, it means non-reducing sugar.

As shown in Figure 4, due to the hydrolysis of sugar in acidity state of syrup during heating up after fermentation and aging, the total reducing sugar was highly significantly increased at 95% of confidence value. Due to the sucrose was transformed to alcohol by yeast, the greater reducing sugars such as glucose and fructose was yielded. In treatment 4, there was highest increased total reducing sugar (250%) followed by treatment 2 and 3 which implied similar rate (115% and 117% respectively). Treatment 1 produced lowest increased total reducing sugar (87.5%). Black jasmine rice wine was classified into sweet wines group because of total reducing sugar which greater than 5%.

Comparison of reducing sugar between 4 treatments showed treatment 1 and 2, in before fermentation state and prepared from 1:3 syrup ratio yielded average reducing sugar was significantly higher than treatment 3 and 4 which prepared from 1:5 syrup ratio (3.21-4.11% compared to 2.16-2.33%). For after fermentation state, treatment 1 and 3 which were TSS adjusted to 20 ^{o}Brix produced average reducing sugar which was lower than treatment 2 and 4 which were 25 ^{o}Brix TSS adjusted (7.57-8.86 % compared to 5.06-6.02 %).

3.5 Black Jasmine Rice Red Wine Physical and Sensory Evaluation

The physical and sense quality of black jasmine rice red wine from 10 days fermentation of 4 treatments were clarified by precipitation using bentonite. The aging process was conducted at 4 ^{o}C for 8 weeks. The results were shown in Table 5-6.

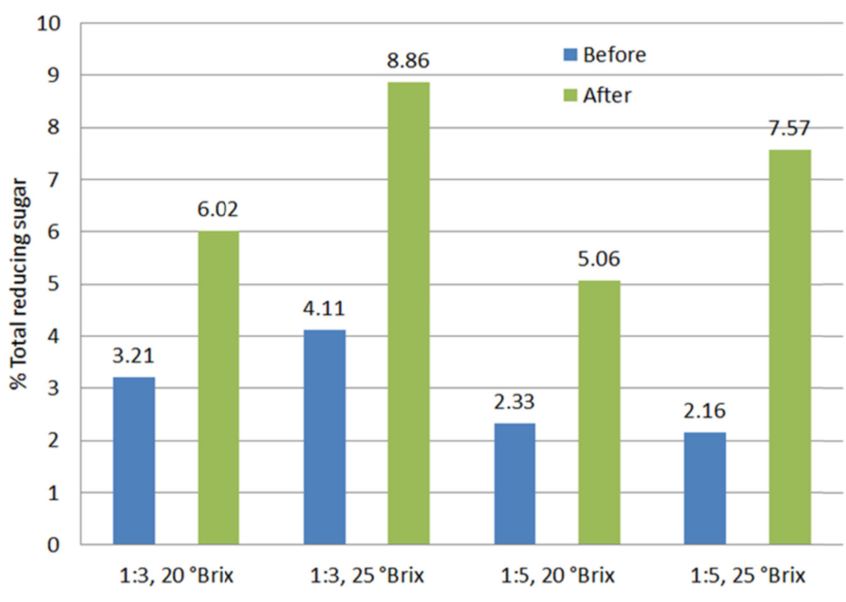

Figure 4. Changes in Total reducing sugar between before and after fermentation process

Table 5. The effect of the ratios between rice starch with water and TSS on the color

Treatments	Color		
	L*	a*	b*
1:3, 20 °brix	49.89±4.49^{bc}	27.55±3.75^{a}	4.41±1.90^{a}
1:3, 25 °brix	47.57±3.55^{c}	29.02±3.18^{a}	2.41±1.99^{b}
1:5, 20 °brix	53.14±2.05^{b}	23.91±2.89^{b}	0.68±0.90^{b}
1:5, 25 °brix	56.76±2.17^{a}	20.44±4.61^{b}	-1.45±2.63^{c}

a-c: Different superscript letters within a column denote significant differences (p<0.05).

Table 6. The effect of the ratios between rice starch with water and TSS on the acceptance score

Sensory characteristics	Treatments			
	1:3, 20 °Brix	1:3, 25 °Brix	1:5, 20 °Brix	1:5, 25 °Brix
Color	4.20±1.37^{b}	4.59±1.17^{b}	6.90±1.93^{a}	7.25±1.47^{a}
Clarity	5.10±1.67^{c}	6.05±1.30^{b}	5.90±1.73^{bc}	7.10±2.06^{a}
Aroma	6.80±1.73^{bc}	7.70±2.17^{a}	6.40±1.52^{c}	7.30±1.69^{ab}
Body^{ns}	6.30±2.01	6.10±1.95	6.85±1.84	6.95±1.69
Sweetness	4.50±2.16^{b}	6.30±1.81^{a}	3.55±1.69^{c}	7.10±1.86^{a}
Bitterness	5.50±2.43^{b}	5.25±2.12^{b}	3.95±2.23^{c}	7.25±1.95^{a}
Overall	5.85±1.64^{b}	6.30±1.44^{b}	6.40±1.53^{b}	7.20±1.58^{a}

a-c: Different superscript letters within a row denote significant differences (p<0.05).

3.6 The Color Quality Test

Table 5 displayed color values of red wine made from black jasmine rice after 8 weeks of aging. The Figure 5 to compared red wine color between black jasmine rice and black sticky rice. It was found those 4 treatments produced significantly different color values p≤0.05). In overall, the wine prepared from 1:5 ratio has lightness value (L) that higher than sample prepared from 1:3 syrup ratio, particularly in treatment 4 which produced highest lightness (56.76±2.17). The high value of L* indicated the great clarity of wine. The wine prepared from 1:3 syrup ratio produced high value of a*, particularly in treatment 2 which produced highest a* (29.02±3.18), revealed that sample was more red intensity than others (Kwak et al., 2012).

Figure 5. Red wine made from black rice. Left: black jasmine rice; Right: black sticky rice

After compared color value of red wine made from black jasmine rice to black jasmine rice syrup sample used in fermentation (Table 2), the red intensity of wine was reduced from 31.29-31.66 to 20.44-29.02 and the lightness was increased from 33.57-39.37 to 49.89-56.76, due to the influence from precipitation by bentonite which lost anthocyanin with sediments. The fermentation process was terminated by adding potassium metabisulfite (0.2 g/L) which affected to anthocyanin bleaching (Waterhouse & Kennedy, 2004).

3.7 Wine Sensory Evaluation

Sensory evaluation of black jasmine rice red wine was conducted by 9-point hedonic scale test. Three main characteristics were evaluated: 1) external characteristics such as color and clarity; 2) texture characteristic such as body; 3) smelling and taste such as aroma, astringency, sweetness and overall acceptance (Grainger, 2009). The results were shown in Table 6 and Figure 6.

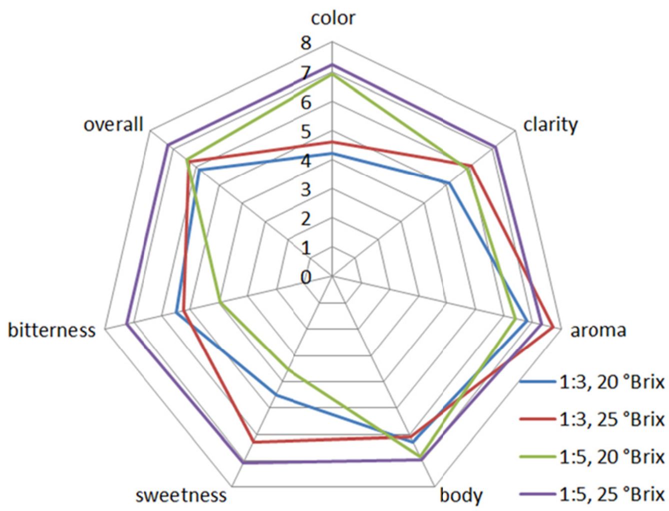

Figure 6. Acceptance score using hedonic scale plot by seven characteristics

Color acceptance of red wine made from black jasmine rice showed averaged values ranged in 4.20-7.25. The red wine made from 1:5 syrup ratio, both 20 °Brix and 25 °Brix TSS in treatments, obtained highest hedonic score (6.90±1.93 and 7.25±1.47 respectively) which were in "like moderately" and "very like" level. The color of red wine made from black jasmine rice was natural red as black jasmine rice color and the pigment was general anthocyanin (González-Neves et al., 2010).

There were various color shades in this kind of pigment such as blue, dark blue (basic, pH>7), purple (neutral, pH=7) and orange to dark red (acidic, pH<7). But wine was high acidic, then anthocyanin produced red color.

The results of clarity acceptance indicated well-clarity of black jasmine rice red wine. The wine made from 1:5 syrup ratio and 25 °Brix TSS adjusted obtained the highest clarity score, significantly differed from other treatments ($p \leq 0.05$). The average score was 7.10±2.06, "like moderately" level. The red wine made from 1:3 syrup ratio with 20 °Brix TSS adjusted obtain the lowest clarity score (5.10±1.67) which was in "neither like nor dislike" level.

The results of aroma acceptance illustrated red wine made from 1:3 syrup ratio with 25 °Brix TSS adjusted and 1:5 syrup ratio with 25 °Brix TSS adjusted obtained hedonic score which was greater than others (7.30-7.70, "like moderately" to "like very much" level). The acceptance in both 2 treatments obtained from testers belonged to ester aroma which clearly evaporated from yeast fermentation process.

For body acceptance, it means sense within mouth and tongue which felt mass and density of product while drinking. Every treatment of black jasmine rice red wine obtained significantly indifferent scores ($p > 0.05$) with 95% of confidence value. The scores ranged in 6.10-6.95 which were in "like slightly" and "like moderately" level. Due to body depends on alcohol concentration, while every wine samples have similar last alcohol concentration, the testers marked indifferent scores.

The results of sweetness acceptance showed red wine with 25 °Brix TSS adjusted, made from both 1:3 and 1:5 ratios, obtained like scores ranged in 6.30-7.10 which were in "like slightly" to "like moderately" level. Because of testers prefer sweeten wines and sweetness comes from sugar remained from fermentation. It was found both 2 treatments remained a lot of TSS after yeast fermentation process and high amount of reducing sugar which caused sweetness as testers preferred.

Some parts of bitterness acceptance depended on alcohol content, production process and amount of phenolic, anthocyanin and tannin compounds which resided in syrup. The wine prepared from 1:5 syrup ration with 25 ^{o}Brix TSS adjust obtain highest score from testers (7.25±1.95, "like moderately" to "like very much" level) due to these wine samples have fit well sweetness and taste balance which come from suitable ratios.

For overall acceptance, it was found the wine prepared from 1:5 syrup with 25 ^{o}Brix TSS adjusted obtained highest score (7.20±1.58). It means the wine quality was satisfied and acceptable in the level of "like moderately" and "like very much" (Grainger, 2009). Other wine samples obtained scores ranged in 5.58-6.40 which were not significantly different ($p>0.05$).

4. Conclusions

The black jasmine rice red wine production has been conducted by study in 2 levels of ratio between black jasmine rice and clean water (1:3 and 1:5) and 2 different levels of TSS (20 and 25 ^{o}Brix) which affected to the quality of red wine made from black jasmine rice. It was found the most suitable conditions for fermentation were 1:5 syrup ratio and 25 ^{o}Brix TSS adjusted. After 8 weeks of aging at 4 ^{o}C, the wine obtained highest score of sensory evaluation, color, clarity, sweetness, bitterness, aroma and overall satisfaction and significantly differed from other treatments ($P<0.05$) . The obtained average scores were in "like moderately" and "like very much" level in all characteristics excepted for body characteristic. A guideline for quality improvement of red wine made from black jasmine rice aimed for higher acceptance is improvement in body. The red wine prepared by that treatment contained 12.45% of alcohol content, 9.25 ^{o}Brix of TSS, 0.17 g/100 mL of total phenolic, 315.11 mg/L amount of anthocyanin, 7.57% of reducing sugar, 3.48 pH and L*, a* and b* color values were 56.76, 20.44 and -1.45, respectively.

Conflict of Interest

No conflict of interest declared.

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