Identification of Various Colored Monascus sp and its Biopigments and Citrinin Production in RMR

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Abstract: The isolation of the orange-colored Monascus spp (YK21A, YK27A, and PN29A) and white-colored Monascus spp (YK21B, YK27B, and PN29B) has been done from commercial red mold rice (RMR). The purpose of this study was to identify the species of Monascus spp and study the biosynthesis of pigments and citrinin in RMR. The species identification is done molecularly using amplification of the partial β-tubulin gene. Solid fermentation with rice substrate for 14 days was used to determine the biosynthesis of pigments and citrinin. Based on the results of molecular identification, it was known that both orange- and white-colored Monascus were Monascus purpureus. The total pigments of Monascus obtained from fermentation were 267.08-367.00 AU/g and 56.54 - 86.83 AU/g, with hue values ranging from 25.4-32.0 and 34.4-49.2 respectively to orange and white ones. While the resulting citrinin was 11.44-113.68 ppm and 0.38-0.86 ppm respectively for the orange and white ones. Strong correlation between total pigment and citrinin ($R^2 = 0.8046$) and between hue and citrinin ($R^2 = -0.8853$) were indicated.

Keywords: Monascus purpureus, pigments, hue, citrinin.

1. Introduction

Monascus spp. are mostly used to make fermented products, such as angkak or red mold rice (RMR), rice wine, and kaoliang brandy in Asia countries. RMR is a fermentation product of Monascus with cooked rice as a substrate. During fermentation, Monascus sp. exhibits main secondary metabolites used for food colorant. RMR is not only used for a food supplement, but is also used to recover digestive system, promote blood circulation, and lower blood cholesterol levels [1-2].

Monascus is classified into Ascomycetes group and family Monascaceae. Generally, Monascus species used in producing RMR are M. purpureus, M. pilosus, M. ruber, M. anka or M. kaoliang [3-7] which also exhibit pigment. Monascus sp. could grow quickly on red yeast rice extract agar (RYREA) and malt extract agar (MEA) media, but grow slowly on potato dextrose agar (PDA) media. At the beginning phase of growth, Monascus sp. colony appears white, then turns into pale pink, red purple, or grayish black at mature phase depending on the species [8].

Pigment of Monascus is synthesized through polyketide pathway yielding hexaketide chromophore and through lipid biosynthesis pathway yielding β-ketoadic. The esterification of two compounds produces monascorubrin, an orange pigment [9]. Six classes of pigments synthesized by Monascus are monascorubrin and rubropunctatin (orange), ankaflavin and monascin (yellow), rubropunctamin and monascorubramin (red) [10-11]. Monascus sp. is also able to produce polyketide mycotoxin, citrinin, that is nephrohepatotoxic, so widely that it can be a potential threat to the acceptance of RMR. The synthesis of citrinin is highly affected by microorganism type, culture medium, and fermentation condition [9, 12]. M. purpureus and M. ruber potentially produce similar citrinin, but differ with M. pilosus.

The isolation of Monascus sp. from commercial RMR in Indonesia on PDA media produces different Monascus colonies varying in color. Most of them are orange, and less of them are white. On this present study, the determination of species from two colored Monascus colonies and the identification of synthesis of pigment and citrinin in RMR production were done.

2. Material and Methods

2.1 Cultivation of the Monascus spp.

Six isolates from commercial angkak used in this study, namely Monascus sp. YK21A, Monascus sp. YK21B, Monascus sp. YK27A, Monascus sp. YK27B, Monascus sp. PN29C and Monascus sp. PN29B were cultivated on agar slant of Potato Dextrose Agar (PDA) medium, incubated at room temperature (28-30°C) for 7 days, stored at 4°C and rejuvenated every four weeks. As a reference culture for species identification, Monascus purpureus FNCC60008 obtained from Food and Nutrition Culture Collection, Universitas Gadjah Mada, Yogyakarta, Indonesia was used for validation.
2.2 Identification of Monascus spp.:

2.2.1 Isolation of genomic DNA:
The extraction of DNA genome for each isolates followed protocol of Cenis [13] with a slight modification as follows. The mycelia from 7-days Monascus in potato dextrose broth (PDB) were centrifuged at 13,000 rpm for 5 minutes until the pellet formation was done. The pellet was washed by 500 μL of buffer TE twice and then extraction buffer was decanted and the mycelia were grounded manually by using conical grinder. After that, Na-acetate was added and kept stored at freezer for 10 to 15 minutes at -20°C. The mixture was centrifuged for 5 minutes and the supernatant contained DNA was transferred to a fresh tube and isopropanol (similar volume) was soaked into it, then kept at room temperature for 15 minutes. DNA pellet was centrifuged briefly and then washed by 70% ethanol. The pellet was dried by using vacuum drier and resuspended in 50 μL TE buffer.

2.2.2 DNA Amplification
DNA amplification was done according to[14] by polymerase chain reaction (PCR). Partial beta tubulin forward primer (5’-CAACTGGGCTAAGGTCATT-3’) and reverse primer (5’-GTGAACTCC ATTCGGTCCATA-3’) were used to amplify DNA. The PCR was performed in a 25 μL reaction mixture containing 2 μL DNA (about 50 ng genomic of Monascus DNA as a template), 0.2 mM primer, 2 units Taq DNA polymerase, 800 mM dNTP, and free-RNase aquabidest was added up to 25 μL. The amplification reaction was performed using Bio-RAD thermal cycler. The reaction was performed including pre-denaturation at 95°C for 2 minutes, followed by 30 successive cycles: denaturation at 95°C for 1 minute, annealing at 52°C for 30 seconds, extension at 72°C for 2 minutes, and final extension at 72°C for 10 minutes. An aliquot of the PCR amplification product was electrophoresed in a 1% agarose gel, stained and observed under ultraviolet light to compare with DNA ladder. The molecule size was approximately 10 kb. The sequencing was carried out by using two aforementioned primers.

2.2.3 Sequencing
DNA sequencing was performed at Laboratory of Sequencing Service, 1st Base-Malaysia. The sequencing was carried out by using primer partial β-tubulin. The sequencing results were checked and edited for making consensus sequences by using Bio-edit program, then were aligned with Clustal W to investigate the presence of sequence variations from samples obtained by using MEGA 6.0 program. DNA sequence was identified by using BLAST program on NCBI.

2.3 RMR preparation:
A long grain white rice IR64 was purchased from local market. Afterwards, it was washed under tap water and was wind-dried at 40°C until moisture content of 13.5% (according to initial state of moisture content). Fifty-grams of rice was transferred to Erlenmeyer flask and the surrounding relative humidity was set about 50%. The sterilization of rice was done using oven at 121°C for 15 minutes. After cooling, the substrates were inoculated with 10% of spore suspensions (1×10⁷ spores per gram substrate) and then was re-incubated for 12 days at 30°C. After 12 days, the RMR was dehydrated in oven at 45°C for 12 to 14 hours. The dried RMR was weighed to determine dry mass percentage and next, it was grounded into fine powder for moisture content measurement [15]. The abovementioned procedure was performed in duplicate for 2 batches fermentation.

2.4 Color measurement
The color measurement of sample using Chroma Meter CR-400 followed the manual instructions of the manufacturer (Minolta Co. Ltd., Osaka, Japan). The Chroma Meter was calibrated with white color standard plate CR-400 prior to use. The color space reading included L* (lightness): a range of 0 (black) to 100 (white), a* (redness) indicating the direction of +/-(red/green) and b* (yellowness) indicating the direction of +/-(yellow/blue). The hue angle (‘hue’) was determined as (tan⁻¹ b*/a*) and the chroma as √(a*² + b*) showing the color and saturation of color, respectively [16, 17]. Each sample was measured thrice for each batch replication.

2.5 Pigments extraction:
RMR was extracted by diluting 75% ethanol at a ratio 1:5 (w/v). The mixture was shook at 200 rpm by using rotary shaker for 1 hour and then was sieved through Whatman No. 1 filter paper. The extract was centrifuged at 10,000 rpm for 5 minutes and measured using spectrophotometer (Shimadzu UV - 1280) at λ 400 nm for yellow pigment, 470 nm for orange pigment, and 500 nm for red pigment. More dilution was needed when the absorbance value exceeded a value of 1.00. The absorbance unit was expressed as OD value multiplied by dilution factor and volume extract per gram sample [18].

2.6 Citrinin measurement:
Citrinin quantification was done using ELISA method assisted by Ridascreen®Fast Citrinin (r-biopharm) procedure. Absorbance at λ 450 nm value was recorded in a micro plate reader (optic ivyam system 2100-C). The limit detection was 15 ppb. The absorbance values were converted to levels of citrinin by using the software of Ridasoft Win.NET - FAST citrinin. The tests were performed twice and the data were presented as a mean ± SD.

3. Results and Discussion

3.1 Identification of Monascus spp.

DNA genome from 6 isolates was successfully amplified and sequenced with a pair of partial beta tubulin primer. The sequence length obtained was 919 pb. Alignment from six isolates with Clustal W showed an absent variation of DNA sequence and they were identical with reference isolate used. The DNA sequencing results with beta tubulin primer confirmed that six isolates were Monascus purpureus. Similarity percentage as high as 99.9% indicated for M. purpureus CICC40269 (AC KP259286.1), M. purpureus
BCBC31747 (AC JX221439.1), M. purpureus BCBC31746 (AC JX221438.1), and M. purpureus BCBC31542 (AC JX221432.1). In short, M. purpureus was not always assigned with orange in color because the presence of 3 white-colored isolates (YK21B, YK27B dan PN29B) were also identified as Monascus purpureus. For another instance, the white-colored colony from Monascus species is M. mucoroides [3]. The distinctive feature among three isolates with M. mucoroides was ascospore size. The ascospore size of M. mucoroides (8 μm) was greater than that of M. purpureus.

3.2 The effect of colony appearance on RMR

From the results obtained, fermentation condition used on this present study did not significantly affected the yield of RMR (Table 1). It showed that all isolates were able to convert rice as a substrate to fermented products. Macroscopic balance during fermentation was briefly explained by [19] where the reaction between rice and O₂ are account for biomass, CO₂, H₂O, ethanol, and acetic acid. The PN29B isolate had the highest dry mass percentage which meant that it had lowest activity in substrate degradation. Those attributes were contrast to PN29C. Dry mass is absolutely affected by fermentation condition and Monascus strain. This present study obviously confirmed that dry mass was affected by Monascus strains.

<table>
<thead>
<tr>
<th>Isolates</th>
<th>Dry mass (%)</th>
<th>Moisture (%)</th>
</tr>
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<tbody>
<tr>
<td>YK21A</td>
<td>46.10 ± 2.63</td>
<td>8.69 ± 0.76</td>
</tr>
<tr>
<td>YK27A</td>
<td>48.98 ± 10.62</td>
<td>9.73 ± 0.09</td>
</tr>
<tr>
<td>PN29C</td>
<td>36.69 ± 2.89</td>
<td>9.78 ± 0.76</td>
</tr>
<tr>
<td>YK21B</td>
<td>38.05 ± 3.83</td>
<td>9.30 ± 1.49</td>
</tr>
<tr>
<td>YK27B</td>
<td>44.11 ± 2.84</td>
<td>8.51 ± 0.20</td>
</tr>
<tr>
<td>PN29B</td>
<td>55.18 ± 5.88</td>
<td>8.85 ± 0.90</td>
</tr>
</tbody>
</table>

3.3. Color value of RMR

The color difference observed in isolated colony showed the difference of pigment synthesis during fermentation (Fig. 1). A noticed difference could be observed among orange- and white-colored isolates of RMR. The difference was especially seen on lightness and hue values. The high value of lightness and hue showed pale red on RMR. In contrast, the low value of lightness and hue showed intense red on RMR. Pigment biosynthesis in producing colors on RMR was also similar (Fig. 2).

The ratio 500nm/400nm of YK21B isolate was more than 1 which meant that the extract was red, but the hue value of YK21B was higher than that of three orange-colored isolates of Monascus. Even though the value of ratio 500/400 was more than 1 but the total pigment was low, it could be summed up that the resulting color of RMR from YK21B isolate was pale red.

3.4 Citrinin synthesis

Citrinin content from colored Monascus colonies was shown in Table 2.

<table>
<thead>
<tr>
<th>Isolates</th>
<th>Total pigment (AU/g)</th>
<th>Citrinin (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>YK21A</td>
<td>267.08 ± 5.05</td>
<td>27.14 ± 5.73</td>
</tr>
<tr>
<td>YK27A</td>
<td>269.32 ± 21.28</td>
<td>11.44 ± 10.17</td>
</tr>
<tr>
<td>PN29C</td>
<td>367.00 ± 22.00</td>
<td>113.68 ± 21.04</td>
</tr>
<tr>
<td>YK21B</td>
<td>86.83 ± 0.42</td>
<td>0.38 ± 0.17</td>
</tr>
<tr>
<td>YK27B</td>
<td>56.54 ± 3.98</td>
<td>0.86 ± 0.50</td>
</tr>
<tr>
<td>PN29B</td>
<td>62.31 ± 14.73</td>
<td>0.44 ± 0.11</td>
</tr>
</tbody>
</table>
The biosynthesis of pigment and citrinin obtained from six isolates showed a strong correlation. The correlation between total pigment synthesis and citrinin (R² = 0.8046) demonstrated that the capability of red-colored Monascus isolates in producing secondary metabolites were higher than that of white-colored ones because the red ones produced higher level of total pigment and citrinin than the white ones. Corresponding to the result, a strong association between hue and citrinin (R² = 0.8853) was indicated. The lower the hue value (the redder the colony), the higher the citrinin content.

4. Conclusion

The white-colored Monascus purpureus was not capable to yield color and high pigment product. However, the result of present study suggested that white-colored Monascus isolate can be potentially used for further research in terms of production of other beneficial compounds.

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References


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