INTISARI

Masyarakat Indonesia memiliki pola konsumsi pangan yang tergantung pada beras sehingga berdampak pada peningkatan prevalensi penyakit degeneratif seperti diabetes. Hal ini mendorong berbagai penelitian untuk mengembangkan pangan yang mengandung pati resisten. Pembentukan pati resisten akibat retrogradasi dan kompleks amilosa-lipida telah dilaporkan di sistem model namun pembentukan kompleks amilosa-lipida di sistem pangan belum dilaporkan. Penelitian ini bertujuan untuk (i) mengetahui kadar amilosa dan pati resisten pada 9 sampel beras, (ii) menentukan karakteristik sifat fisik, kimia, dan gizi tepung dan pati pada varietas beras terpilih, (iii) menentukan perubahan struktur pati dan peningkatan kadar pati resisten nasi akibat pendinginan dan pemanasan secara berulang, (iv) menentukan perubahan struktur pati dan peningkatan kadar pati resisten nasi akibat penambahan lipida, (v) menentukan mekanisme pembentukan RS5 pada nasi yang ditanak dengan lipida.

Penelitian ini dibagi menjadi 3 tahap, yaitu seleksi sampel beras dan karakterisasi sampel beras terpilih, rekayasa pendinginan dan pemanasan secara berulang pada nasi, dan penambahan lipida pada nasi yang didinginkan dan dipanaskan secara berulang. Ke-9 sampel beras diseleksi berdasarkan kadar amilosa dan pati resisten tertinggi. Tepung dan pati beras terpilih selanjutnya dikarakterisasi sifat fisik, kimia, dan gizinya. Rekayasa pendinginan dan pemanasan nasi secara berulang dilakukan 1-2 kali dengan kondisi pendinginan pada suhu 4°C selama 12 jam dan pemanasan *microwave* selama 90 detik. Penambahan lipida berupa santan atau minyak kelapa dilakukan dalam penanakan nasi. Nasi disebut sebagai sistem pangan sedangkan tepung atau pati beras yang dicampur dengan asam laurat, asam kaprilat, asam miristat dengan rasio 65:18:17 disebut sebagai sistem model. Karakteristik sifat fisik meliputi pola difraksi sinar-X dan suhu T_o, T_p, T_c. Karakteristik sifat kimia meliputi spektra FT-IR dan ^{13}C-NMR. Karakteristik sifat gizi meliputi kadar pati resisten, kecernaan pati secara *in vitro*, HI, dan PGI.

Hasil penelitian menunjukkan beras Setra Ramos memiliki kadar amilosa (23,34%) dan kadar pati resisten (21.13%) tertinggi sedangkan beras Mentik Susu memiliki kadar amilosa (15,22%) dan kadar pati resisten (10,39%) terendah. Semakin tinggi kadar amilosa dalam varietas beras tertentu, maka semakin tinggi kadar pati resistennya. Pati beras Setra Ramos dan Mentik Susu memiliki pola difraksi sinar-X tipe A. Kristalinitas paling tinggi terdapat pada pati beras Mentik Susu sedangkan kristalinitas paling rendah terdapat pada tepung beras Setra Ramos. Suhu puncak gelatinisasi T_p pati beras Setra Ramos dan Mentik Susu lebih tinggi dibandingkan tepung beras Setra Ramos dan Mentik Susu. Granula pati beras Setra Ramos dan Mentik Susu berbentuk *irregular* polihedral dan berukuran rata-rata 2,8 μm. Kadar protein pati beras Setra Ramos dan Mentik Susu lebih rendah daripada tepung beras Setra Ramos dan Mentik Susu dengan kadar lemak kurang dari 1%. Pola spektra FT-IR tepung dan pati beras Setra Ramos dan Mentik Susu hampir sama untuk ikatan α-1,4 glikosidik pada 1157

cm^{-1} dan *skeletal modes* amilosa dan amilopektin pada 400 cm^{-1} dan 900 cm^{-1}. Pola spektra ^{13}C-NMR tepung dan pati beras Setra Ramos dan Mentik Susu sama untuk C1 pada 99-100 ppm, C2, C3, C5 pada 70-71 ppm, C4 pada 78 ppm, dan C6 pada 61 ppm. Pati beras Mentik Susu paling mudah dicerna secara *in vitro* sedangkan tepung beras Setra Ramos paling sulit dicerna secara *in vitro* selama 120 menit.

Perubahan struktur pati akibat retrogradasi selama pendinginan dan pemanasan berulang ditunjukkan dengan perubahan pola difraksi sinar-X pada 18º dan 23º 2θ, peningkatan kristalinitas pati dan suhu T_o, T_p, T_c, perubahan amplitudo di pita 1018 cm^{-1}, dan penurunan puncak 73 ppm untuk C2, C3, dan C5 dari α-glukosa. Nasi tanpa pendinginan dan pemanasan memiliki kadar pati resisten 1,25%, HI 69,18, dan PGI 77,69. Pengulangan pendinginan dan pemanasan sebanyak 2 kali akan meningkatkan kadar pati resisten nasi 3,5 kali dan menurunkan HI menjadi 51,28 dan PGI menjadi 67,86.

Perubahan pola difraksi sinar-X pada 21º dan 23º 2θ, pembentukan 2 puncak endotermik, penurunan indeks iodin-pati, adanya puncak 1743 cm^{-1} pada spektra FT-IR dan 2 puncak 100 ppm pada spektra ^{13}C-NMR mengindikasikan pembentukan RS5 dalam nasi yang ditanak dengan santan. Nasi yang ditambah santan tanpa pendinginan dan pemanasan memiliki kadar pati resisten 5,35%, HI 40,03, dan PGI 61,69. Pengulangan pendinginan dan pemanasan sebanyak 2 kali hanya meningkatkan kadar pati resisten nasi kurang dari 0,5% walaupun menurunkan HI dan PGI. Puncak 21˚ 2θ pada pola difraksi sinar-X mengindikasikan pembentukan RS5 dalam nasi yang ditanak dengan minyak kelapa walaupun pita kuat 1743 cm^{-1} tidak terdeteksi pada spektra FT-IR. Nasi yang ditambah minyak kelapa tanpa pendinginan dan pemanasan memiliki kadar pati resisten 1,61%, HI 68,59, dan PGI 77,37. Pengulangan pendinginan dan pemanasan sebanyak 2 kali pada nasi yang ditambah minyak kelapa memberikan pengaruh yang sama pada kadar pati resisten nasi yang ditambah santan. RS5 lebih mudah terbentuk pada sistem model dibandingkan sistem pangan dan teridentifikasi pada pola difraksi sinar-X 17º, 20º, 21º, 23º 2θ dan pita 1743 cm^{-1} dan 1635 cm^{-1} spektra FT-IR. Mekanisme pembentukan kompleks RS5 dimulai pada saat gelatinisasi dan RS5 yang terbentuk distabilkan selama retrogradasi.

Kata kunci: pati, nasi, santan, retrogradasi, RS5

ABSTRACT

Food consumption pattern of Indonesian people still depend on rice. This condition could be impact to the increasing of degenerative diseases prevalence such as diabetes. Therefore numerous studies have been done to explore the food products containing resistant starch. There are many studies focused on formation of resistant starch in model system due to retrogradation and amylose-lipid complexes have been reported but formation of amylose-lipid complexes in food system still limited. The objectives of this research were (i) to know the amylose and resistant starch content in 9 rice samples, (ii) to determine the physical, chemical and nutritional properties of the selected rice flour and rice starch, (iii) to determine the structural changes of starch and the increasing of resistant starch content due to recooling and reheating process, (iv) to determine the structural changes of starch and the increasing of resistant starch content due to lipid addition, (v) to determine the mechanism of RS5 formation on cooked rice with lipid addition.

This research was divided into 3 steps, i.e. (i) the selection of 9 rice samples and characterization of selected rice flour and rice starch, (ii) the cooling and heating treatment, (iii) the addition of lipids. The ninth rice samples selected based on their amylose and resistant starch content. The cooling and heating process were done 1-2 times with cooling condition at 4ºC for 12 h and microwave heating for 90 sec. The addition of lipids, i.e. coconut milk and coconut oil were done during rice cooking. Cooked rice called as food system, whereas rice flour or rice starch which mixed with lauric acid, caprylic acid, myristic acid (ratio 65:18:17) called as model system. Physical properties were diffraction pattern and T_o, T_p, T_c whereas chemical properties were spectra FT-IR and ^{13}C-NMR. Nutritional properties were resistant starch content, in vitro starch hydrolysis rate, HI and PGI.

The results showed that Setra Ramos rice had the highest amylose content (23.34%) and resistant starch content (21.13%) whereas Mentik Susu rice had the lowest amylose content (15.22%) and resistant starch content (10.39%). Resistant starch content increased with the increase in amylose content. Rice starch of Setra Ramos and Mentik Susu had A-type diffraction pattern. The highest crystallinity was found on rice starch of Mentik Susu whereas the lowest crystallinity was found on rice flour of Setra Ramos. The gelatinization peak T_p of rice starches of Setra Ramos and Mentik Susu were higher than their rice flours. Rice starches of Setra Ramos and Mentik Susu were irregular polyhedral shaped, with average width 2.8 μm. The protein content of rice starch of Setra Ramos and Mentik Susu were lower than their rice flours with lipida content lower than 1%. The IR analysis for all samples showed a band at 1157 cm^{-1} associated to α-1.4 glycosidic linkage starches and a band at 400 cm^{-1} and 900 cm^{-1} corresponding to skeletal modes of amylose and amylopectin. The spectrum of ^{13}C-NMR supports the results obtained by IR. Rice starch of Mentik Susu was easiest to be hydrolyzed whereas rice flour of Setra Ramos was hardest to be hydrolyzed within 120 min.

The changes of diffraction pattern at 18º and 23º 2θ, increasing of crystallinity and T_o, T_p, T_c, decreasing of iodin-starch indexes, the changes of amplitude in the band FT-IR at 1018 cm^{-1} and decreasing of peak ^{13}C-NMR at 73 ppm indicated the structural changes of starch due to retrogradation during recooling. Cooked rice without recooling-reheating treatment had resistant starch content 1.25%, HI 69.18 and PGI 77.69. Repeated cooling and heating 2 times increased resistant starch content 3.5 times and decreased HI to 51.28 and PGI to 67.86.

The changes of diffraction pattern at 21º and 23º 2θ, the formation 2 endothermic peaks, the presence of band FT-IR at 1743 cm^{-1} and the presence of 2 peaks ^{13}C-NMR in 100 ppm indicated the formation of RS5. Cooked rice with coconut milk addition without recooling-reheating treatment had resistant starch content 5.35%, HI 40.03 and PGI 61.69. Repeated cooling and heating 2 times increased resistant starch content 0.5% although HI and PGI decreased. The indication of RS5 formation in cooked rice with coconut oil addition was confirmed only with the presence of the diffraction at 21º 2θ. Cooked rice with coconut oil addition without recooling-reheating treatment had resistant starch 1.61%, HI 68.59 and PGI 77.37. The effect of repeated cooling and heating 2 times on cooked rice with coconut oil addition was similar to cooked rice with coconut milk addition. The formation of RS5 was easier in model system compared to food system and clear identified with X-ray diffraction pattern 17º, 20º, 21º, 23º 2θ and bands 1743 cm^{-1} and 1635 cm^{-1} of spectra FT-IR. Mechanism of formation of RS5 begins at gelatinization and its complexes stabilized during retrogradation.

Keywords: starch, cooked rice, coconut milk, retrogradation, RS5