The Effect of Autoclaving-Cooling Cycling Treatment on Functional, Sensory and Microstructure Properties of Artificial Rice

P Luna1*, M R K Putra1, E Mulyono A1, and A. A. Sulaiman2

1Indonesian Center for Agricultural Postharvest Research and Development, Bogor, 16122
2Ministry of Agriculture, Jakarta, 12550

*Email: primaluna@litbang.pertanian.go.id

Abstract. Artificial rice is an alternative product towards food security in Indonesia. The artificial rice in this study was produced from indigenous cereals and tuber flours. The aim of this study was to investigate physical, functional and microstructure properties of the artificial rice as influenced by autoclaving-cooling cycling treatments on its flour material. In this study, the processing treatments applied to the flour material were autoclaving at 121 °C for 15 minutes followed by cooling at 4 °C for 24 hours with three and five cycles. Their effects on the artificial rice properties were compared to that with no autoclaving treatment. The results showed that artificial rice produced from flour treated with five autoclaving-cooling cycles had the highest starch digestibility (~57%) as well as the highest of amylose content (~26%). An organoleptic test was taken place and showed there is no significant differences in all parameters for the three products in terms of colour, flavour, and texture. Microstructure analysis by scanning electron microscopy (SEM) showed that longer cooling treatment led to more cracks intensity on the granule surface of the artificial rice.

1. Introduction

World food security outlook 2045 has influenced Indonesian policy on strengthening national food security. Indonesia has implemented food diversification program to support national food security due to increasing population and demand for rice as a staple food [1]. One product that supports this policy is artificial rice. Artificial rice is reconstituted rice kernel product which can be developed from tubers, cereals, and other desired additives and it has similarity with rice in term of shape and nutrition [2, 3].

Recently, resistant starch (RS) has been a subject of numerous studies due to its functional effect on health such as prevention of colon cancer and glycemic- and cholesterolemic-lowering effects [4]. Criteria of functional food can be determined by RS content [5]. One of methods to develop resistant starch is the autoclaving-cooling process [6]. There are many methods to develop artificial rice namely extrusion [3] and granulation [6].

Indonesia has many local resources as raw materials for artificial rice such as cassava, sweet potato, potato, Dioscorea, sorghum, corn, and sago. All is in flour form. A formulation is important to generate artificial rice’s dough before granulation or extrusion. Additives may be added to get a well-shaped of reconstituted rice and to give more effect on functional such as konjac glucomannan flour. Konjac glucomannan flour is isolated from Amorphophallus konjac (tuber). It is a hydrocolloidal polysaccharide [7]. This additive has a low caloric, soluble dietary fibre and medicine ingredient [8]. It is also used as
supplements [9]. Previous studies stated that konjac has benefit to reduce cholesterol, to maintain triglyceride content, to improve blood sugar levels, to increase immunity, and to promote intestinal activity [10].

The autoclaving-cycling process gives effect on resistant starch properties as reported by Yadav et al. [11]. The number of cycles may affect the kernels’ microstructure and physicochemical and functional properties of the artificial rice. The objective of this research was to investigate the effect of autoclaving-cooling cycling treatment on physical, functional and microstructure properties of artificial rice.

2. Materials and methods

2.1. Materials

The raw materials were cassava flour, corn flour, and other local flour and starch which were purchased from local market. The chemicals used were hexane, KI powder, iodium powder, methylene blue 0.2% in alcohol, amyllum 1%, HCl, KCl, natrium asetat, K$_2$SO$_4$ powder, NaOH-Na$_2$S$_2$O$_3$, H$_3$BO$_3$, concentrated H$_2$SO$_4$, NaOH 1 N, α-amilase, buffer phosphate, maltose and dinitrosalycilic acid (DNS).

2.2. Methods

2.2.1. Application of autoclaving-cooling cycling treatment (modification from Yadav et al. [11])

This treatments were conducted by autoclaving-cooling flours at 121 ºC for 15 minutes and then cooling at 4 ºC for 24 hours with three (F1), and five cycles (F2) treatments against no autoclaving treatment as control (C).

2.2.2. Analysis of artificial rice

Analysis of artificial rice was conducted in the form of analysis of functional component, analysis of sensory characteristic, and microscopic analysis of granular structure. Analysis of functional component, included: starch digestibility by the enzymatic method based on Anderson et al. [12]. Sample preparation for sensory analysis was done by cooking with the addition of ± 1/2 part water of artificial rice. Sensory attributes (colour, flavour, taste, and texture) were assessed based on the method developed by Setyaningsih et al. [13]. Microscopic analysis of granular structure was observed using the SEM technique (SEM ZEISS EVO MA 10) with a detector SE (Secondary Electron), WD (Working Distance) 7 mm and EHT (Extra High Tension) with voltage 18 kV. The samples were sputter-coated with gold prior to examination.

3. Result and discussion

3.1 Physical properties of artificial rice

The autoclaving-cooling process showed different effects on physical appearances of the artificial rice which is depicted in Figure 1. It can be seen that the autoclaving process gave effect on rice colour due to heating process. Artificial rice produced from flour without autoclaving process (control) had a darker colour than those treated with the autoclaving-cooling process due to natural colour of mix ingredients of artificial rice. The result suggests that the autoclaving-cooling process changed the starch properties. In the case of artificial rice, gelatinisation of starch is essential [3]. This process affects in achieving a quick-cooking and non-expanded product. Actual moisture involved in the process is a critical parameter that directly influences starch gelatinisation and final product quality. Nevertheless, starch gelatinisation may have reduced antinutritional factors including amylase inhibitors, leading to the decrease in RS content in all studied samples after autoclaving as mentioned by Kasote et al. [4].
3.2. Starch digestibility

The F1 had lower digestibility starch than control and F2. The cooling process (retrogradation) supposed to change the RS into rapidly digestibility of starch (RDS) [4]. This concept is in agreement with the finding in this study that F2 product had a higher starch digestibility (57%) compared to F1 product (33%) (Figure 2). However, there was no significant difference between control product and F2 product regarding starch digestibility. This is probably because the control product contained low bioavailability of resistant starch, high amylose content, and low presence of amylase inhibitors opposed to the treated samples.

Figure 2. Starch digestibility of artificial rice: Control (C), 3 cycles of autoclaving (F1), and 5 cycles of autoclaving (F2) treatments

Amylose content of artificial rice produced in this study is depicted in Figure 3. It can be seen that F2 product had amylose content (~26%) which was slightly higher among all artificial rice in this study, although there is no significance difference. Amylose content may contribute to the differences in thermal and pasting properties as well as starch digestibility of the artificial rice [14].
Figure 3. Amylose content of artificial rice: Control (C), 3 cycles of autoclaving (F1), and 5 cycles of autoclaving (F2) treatments

3.3. Sensory attributes of artificial rice
Table 1 shows sensory attributes of artificial rice produced. It can be seen that there is no significant differences in all parameters for the three products in terms of colour, flavour, and texture. Overall, the texture of F1 had the highest average value in all parameters. Therefore, the panelists accepted artificial rice F1.

Tabel 1. Organoleptic test of artificial rice

| Sample | Parameters | Colour | Flavour | Taste | Texture |
|--------|------------|--------|---------|-------|---------|
| C      |            | 2.93\textsuperscript{a} | 2.77\textsuperscript{b} | 2.67\textsuperscript{c} | 2.70\textsuperscript{d} |
| F1     |            | 2.96\textsuperscript{a} | 2.80\textsuperscript{b} | 2.45\textsuperscript{c} | 3.06\textsuperscript{d} |
| F2     |            | 2.90\textsuperscript{a} | 2.77\textsuperscript{b} | 2.61\textsuperscript{c} | 2.64\textsuperscript{d} |

Remarks: a) C = control, F1 = autoclaving 3x, F2 = autoclaving 5x. b) Hedonic scale: 1: dislike extremely, 2: dislike very much, 3: like moderately, 4: like very much and 5: like extremely. c) Differences in letters at the top of each value in the same column indicate significant differences between samples (p<0.05).

3.4. Microstructure of artificial rice
It can be seen in Figure 4 that almost all starch granules in the F2 ruptured and became densed. A factor that affect the microstructure of granules was the cooling process. This process increased the resistant starch which led to the increase of percentage retrograded starch. The granules became densed due to the longer the cooling time. Increasing of cooling time also caused cracks in the granular surface. Breakage and cracking of the starch granules due to this heating and cooling treatment also reported by Ashwar et al. [15] and Shin et al. [16].
Figure 4. SEM images of artificial rice: control (C), 3 cycles of autoclaving-cooling process (F1), and 5 cycles of autoclaving-cooling process (F2). Magnification: 2000x

4. Conclusion
The processing heating and cooling methods of artificial rice would affect starch digestibility and amilose content as well as the sensory properties. The cooling time would increase the crack intensity on the starch granules surface of artificial rice. Findings of this study further suggest, processed artificial rice with five times autoclaving-cooling processing could have added health promoting potential due to their high content of resistant starch.

5. References
[1] Anonymous 2017 Vission and Mission Ministry of Agriculture of Republic of Indonesia http://www.pertanian.go.id Retrieved 21 Agustus 2018
[2] Samad MY 2003 Pembuatan Beras Tiruan (Artificial Rice) dengan Bahan Baku Ubikayu dan Sagu. Prosiding Seminar Teknologi untuk Negeri 2003. Vol. II. pp 36-40/Humas-BPPT/ANY, BPPT. Jakarta
[3] Mishra A, Mishra HN and Srinivasa Rao P 2012 Preparation of rice analogues using extrusion technology Int. J. Food Sci. Technol. 47 1789–97
[4] Kasote DM, Nilegaonkar SS and Agte VV. 2014 Effect of different processing methods on resistant starch content and in vitro starch digestibility of some common Indian pulses J. Sci. Ind. Res. (India). 73 541–6
[5] Raigond P, Ezekiel R and Raigond B 2015 Resistant starch in food: a review Resistant starch in food: a review 95, 1968–1978
[6] Hidayat B, Muslihudin M and S A 2018 Application of autoclaving-cooling cycling treatment to improve resistant starch content of corn-based rice analogues Application of autoclaving-cooling cycling treatment to improve resistant starch content of corn-based rice analogues J. Phys. Conf. Ser. 953 012010 1–7
[7] Behera SS and Ray RC 2017 Nutritional and potential health benefits of konjac glucomannan, a promising polysaccharide of elephant foot yam, Amorphophallus konjac K. Koch: A review Food Rev. Int. 33 22–43
[8] Xu W, Wang S, Ye T, Jin Liu J, Lei J, Bin L, Wang C 2014 A simple and feasible approach to purify konjac glucomannan from konjac flour—Temperature effect Food Chem 158 171–176
[9] Tester RF and Al-Ghazzewi FH 2013 Mannans and health, with a special focus on glucomannans. *Food Res. Int.* **50** 384–391

[10] Chua M, Baldwin TC, Hocking TJ and Chan K. 2010 Traditional uses and potential health benefits of Amorphophallus konjac K. Koch ex NE Br *J Ethnopharmacol* **128** 268–278

[11] Yadav BS, Sharma A and Yadav R B 2009 Studies on effect of multiple heating/cooling cycles on the resistant starch formation in cereals, legumes and tubers *Int. J. Food Sci. Nutr.* **60** 258–72

[12] Anderson, AKHS, Guraya C, James and L Savaggio 2002 Digestibility and pasting properties of rice starch heat-moisture treatment at the melting temperature (Tm). *J Starch* **54** 401-409

[13] Setyaningsih D, Apriyantono A and Sari MP 2010 *Analisis Sensori untuk Industri Pangan dan Agro* Bogor (ID) IPB Press

[14] Srichuwong S, Curti D, Austin S, King R, Lamothe L and Gloria-hernandez H 2017 Physicochemical properties and starch digestibility of whole grain sorghums, millet, quinoa and amaranth flours, as affected by starch and non-starch constituents *Food Chem.* **233** 1–10

[15] Ashwar BA, Gani A, Wani IA, Shah A, Masoodi FA and Saxena DC 2016 Production of resistant starch from rice by dual autoclaving-retrogradation treatment: Invitro digestibility, thermal and structural characterization *Food Hydrocolloids* **56** 108

[16] Shin SI, Kim HJ, Ha HH, Lee SH, Moon TW 2005 Effect of hydrothermal treatment on formation and structural characteristics of slowly digestible non-pasted granular sweet potato starch *Starch/Stärke* **57** 421

**Acknowledgements**

The authors would like to thank Indonesian Center for Agricultural Postharvest Research and Development (ICAPRD), Indonesian Agency for Agricultural Research and Development (IAARD), Ministry of Agriculture, Republic of Indonesia for the financial support of this research.