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Identification of aroma, bioactive, and chemical compounds of red and black glutinous rice after processing using a rice cooker

[Identifikasi senyawa aroma, bioaktif dan kimia beras ketan merah dan hitam setelah pengolahan menggunakan rice cooker]

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ABSTRACT

Glutinous rice has different aroma compounds according to its type and variety. Aroma compounds are volatile, especially during the heating process, which causes the loss of some aroma components, alters the chemical composition, and reduces antioxidant activity. This study aimed to identify aroma compounds, chemicals, and antioxidant activity of red and black glutinous rice processed into rice using the rice cooker method. The parameters observed in this study included the identification of aroma compounds, bioactives consisting of total phenols, anthocyanins, and antioxidant actiity. Chemical contents of red and black glutinous rice, including amylose content, water content, ash, fat, protein, and carbohydrates were also analyzed. The results showed that the aromas compounds found in red and black glutinous rice after cooking were dominantly hydrocarbons, aldehydes, and alcohols. The results of the study showed that the highest anthocyanins content and antioxidant activity were found in black glutinous rice, with values of 17.60 ± 0.78 mg/100g and 51.03 ± 1.01%. Meanwhile, the results of chemical parameter observations showed significant differences ($p<0.05$) in water content and ash content, with the highest values in black glutinous rice, namely 43.47 ± 0.01% for water and 0.96 ± 0.02% for ash. Red and black glutinous rice had protein contents of 4.84±0.64% and 4.76±0.03%, respectively, and fat contents of 1.44±0.03% and 1.14±0.01%, respectively. Carbohydrate contents were 51.93±0.06% and 49.71±0.03%. respectively. In comparison, the amylose content of red and black glutinous rice were 1.18±0.06% and 1.22±0.04%. Black glutinous rice processed using a rice cooker has a higher nutritional content compared to that of red glutinous rice.

Keywords: antioxidants, aroma, black glutinous rice, red glutinous rice, rice cooker

ABSTRAK

Beras ketan memiliki senyawa aroma yang berbeda-beda sesuai dengan jenis dan varietasnya. Senyawa aroma mudah menguap terutama selama proses pemanasan yang menyebabkan kehilangan beberapa komponen aroma, komposisi kimia dan aktivitas antioksidan. Penelitian ini bertujuan untuk mengidentifikasi senyawa aroma, kimia dan aktivitas antioksidan beras ketan merah dan hitam yang diolah menjadi nasi menggunakan metode *rice cooker.* Parameter yang diamati pada penelitian ini meliputi identifikasi senyawa aroma, bioaktif yang terdiri atas total fenol, antioksidan dan antosianin serta analisa kimia meliputi kadar amilosa, kadar air, abu, lemak, protein, karbohidrat nasi ketan merah dan hitam. Hasil penelitian menunjukkan bahwa aroma yang teridentifikasi pada beras ketan merah dan hitam setelah pemasakan menjadi nasi meliputi golongan hidrokarbon, aldehida dan alkohol secara kuantitatif dalam jumlah terbesar. Hasil penellitian kandungan bioaktif tertinggi terdapat pada antioksidan dan antosianin nasi ketan hitam dengan nilai 51,03±1,01% dan 17,60 ± 0,78 mg/100g. Sedangkan hasil pengamatan parameter kimia berbeda signifikan ($P<0,05$) terdapat pada kadar air dan kadar abu dengan nilai tertinggi pada nasi ketan hitam yaitu air 43,47±0,01% dan abu 0,96±0,02%. Nasi ketan merah dan hitam miliki kadar protein 4,84±0,64%, dan 4,76±0,03% dan lemak 1,44±0,03% dan 1,14±0,01%, karbohidrat 51,93±0,06% dan 49,71±0,03%. Sedangkan kadar amilosa nasi ketan merah dan hitam yaitu 1,18±0,06 dan 1,22±0,04%. Nasi ketan hitam yang diolah menggunakan *rice cooker* memiliki kandungan gizi yang lebih tinggi jika dibandingkan dengan nasi ketan merah.

Kata kunci: antioksidan, aroma, ketan hitam, ketan merah, *rice cooker*

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Introduction

Glutinous rice is one of the foodstuffs widely consumed by Indonesians. The average per capita consumption of glutinous rice in 2023 was 0.327 (Kg/cap/year). This value was very different from the consumption of ordinary rice, which reached 80.905 (Kg/cap/year) (Pusdatin, 2023). Black glutinous rice production in Indonesia reached 550 tons/year (Pramitasari & Herlina, 2023). The types of glutinous rice commonly consumed by Indonesians vary from black glutinous rice, white glutinous rice, and red glutinous rice. Glutinous rice and regular rice are known to have different starch contents in the form of amylose and amylopectin. Glutinous rice has a low amylose content (<5%) and a high amylopectin content (Chung et al., 2011) and this causes glutinous rice to have a sticky texture after cooking. Meanwhile, regular rice generally has a higher amylose content, ranging from 20-25% in normal or medium rice and up to 30% in high amylose rice (Setyaningsih et al., 2015). Amylose has α-1,4 glycosidic bonds between α-D-glucose or α-D-glucopyranose units, which are linearly connected. Whereas amylopectin has α-1,4 and α-1,6 glycosidic bonds. The α-1,4 glycosidic bonds form a linear structure, and the α-1,6 glycosidic bonds form branching points (Kontogiorgos, 2021).

The nutritional content of glutinous rice, apart from containing pigments, anthocyanins, also contains minerals such as iron, calcium, selenium, zinc, Vitamin B complex, Vitamin E, protein, and fiber (Agustin et al., 2021). Black rice contains more phenolics (0.6% anthocyanins) compared to that of red rice (0.2% proanthocyanidins), whereas non-pigmented brown rice only contains <0.02% phenolics (Shao et al., 2014). Black rice contains anthocyanin pigments in its epidermis (cyanidin-3-glucose and peonidin-3-glucose), making it a good source of antioxidants (Das et al., 2023). Anthocyanin (the glycone form of anthocyanidin) is a flavonoid compound thought to be responsible for the substance that gives brown rice its color, because aleurone contains genes that are thought to produce anthocyanin compounds or other compounds that cause red or purple color (Wang et al., 2022). The antioxidant activity of pigmented rice is higher compared to that of non-pigmented rice (Irakli et al., 2016) in free and bound forms. Anthocyanins have a positive impact on health because they have antioxidant activity. Antioxidants can prevent various non-communicable diseases (NCDs) such as the emergence of cancer cells, atherosclerosis, hypertension, diabetes, osteoporosis, asthma, digestive health, and reduce the risk of stroke in women. Black rice is also used in the development of new food products (Sangma & Parameshwari, 2023).

Hundreds of volatile aroma components have been detected in various types of rice, including aldehydes, ketones, esters, alcohols, heterocycles, and alkenes (Verma & Srivastav, 2020). Several countries have several varieties of fragrant rice, such as Basmati and short and medium grain non-Basmati fragrant rice, which are gaining popularity globally, not only in Asia but also among European and American consumers (Ashokkumar et al., 2020). The dominant aroma contained in glutinous rice is 2-acetyl-1-pyrroline (2-AP); thus, this compound is responsible for the aroma of rice (Routray & Rayaguru, 2018; Haowen et al., 2022). In particular, other volatile compounds such as alcohols, aldehydes, esters, and ketones, also contribute to the production of aroma in rice (Ashokkumar et al., 2020). The aroma of rice after cooking is produced through a comprehensive reaction among the aromatic volatile compounds in it. Differences in the types and components of volatile compounds give different aromas to the rice produced (Hu et al., 2020)

Research on the aroma components of glutinous rice in Indonesia is still very limited. Research on varieties of red glutinous rice and black glutinous rice needs to be carried out to identify aroma components, bioactive compounds, and chemical components of glutinous rice after cooking using a rice cooker. The heat processing process will affect the aroma components of glutinous rice (Prodhan et al., 2017). Furthermore, heat treatment will also damage several bioactive compounds, such as anthocyanins and antioxidant activity, which are sensitive to high temperatures (Ghani et al., 2023). Processing can cause

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damage to anthocyanins due to their tendency to polymerize in the presence of oxygen and heat (Ahmed et al., 2019). Therefore, in this research, a study was carried out to identify the aroma components, the content of bioactive compounds in the form of anthocyanins and antioxidants, and chemical compounds of two types of glutinous rice after heat processing using the method rice cooker.

Materials and methods

Materials and tools

The ingredients used were red glutinous rice and black glutinous rice obtained from Boalemo Regency, Gorontalo Province. The chemicals used in this research were ethanol, acetic acid, Folin-Ciocalteu, Merck reagent (Darmstadt, Germany), 1,1-diphenyl-2-picrylhydrazyl (DPPH), HCl, NaOH, chloroform, buffer pH 1 and 4.5, and iodine. Chemicals used for flavor analysis were methanol, diisopropyl ether, 1,4-dichlorobenzene, N2 gas, distilled water, flavor standards (pandan flavor, gamma nonalactone, acetyl-2-thiazole, gammaundecalactone, diacetyl), basic flavor solution (caffeine, citric acid, NaCl, sucrose), and propylene glycol.

The equipment used was a Miyako rice cooker, basin, micropipette, vortex mixer, water bath, desiccator, analytical balance, oven, Erlenmeyer glass, rotary evaporator, UV-Vis spectrophotometer (Milton Roy 501), UV-Vis spectrophotometer (Shimadzu AA-7000): aluminum container, digital temperature thermometer, and 1000 mL measuring cup. Tools for identifying rice flavor components are glass beads, Vigraux, and GC-MS tools.

Research methods

This research was non-factorial and arranged in a Completely Randomized Design (CRD) with 3 replications. The treatment consisted of two varieties of glutinous rice, namely red glutinous rice and black glutinous rice, which were processed using a rice cooker. The data were subjected to analysis of variance (ANOVA), and continued testing was performed using the Least Significant Difference (LSD) Test. Parameters analysis included aroma, bioactive compounds, and chemical constituents of the cooked samples.

Preparation of cooked glutinous rice

The processing of red glutinous rice and black glutinous rice includes sorting or cleaning using a tampah tool to separate the rice from dirt. A total of 500 grams of glutinous rice was then washed using 1 liter of water 2 times until clean, drained to make it easier to determine the volume of water that will be added when cooking the rice. Then, water was added with a ratio of glutinous rice: water of 1:1.5 liters to result in good rice texture. The glutinous rice was cooked for ±40 minutes at a temperature of ±90℃.

Research parameters

Aroma identification uses GCMS with the maceration method

Glutinous rice samples were extracted with methanol solution then analyzed using a GCMS Agilent 6980N Network GC System with an Agilent 5973 inert MSD (70eV direct inlet) detector. 2 µl of the pipetted extract sample solution was injected into the GCMS which had a J&W Scientific, HP-5MS capillary column with a length of 30 mm. Carrier gas (helium) at a flow rate of 1 ml/minute (constant) with a split ratio of 1:10. The programmed oven temperature is 50°Cand kept isothermal for 5 minutes, the rate increased to 10°C/min and the temperature is increased to 280°C for 15 minutes. injector port temperature is 290°C and the mass spectrometer interface is 230°C. This method wa modified from Kun et al. (2025).

Determination of total phenol content

Analysis of the total phenolic content was carried out using the method developed by Jeong et al. (2004). The Glutinous rice samples were carried out by placing fifty grams of ground glutinous rice in a

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container that had been lined with aluminum foil. Glutinous rice samples were extracted by adding 250 mL of 80% ethanol and maserated for 1 day and then centrifuged for 20 minutes at a speed of 3000 rpm. The supernatant was collected for total phenol analysis as well as determination of free radical scavenging activity in the DPPH free radical system.

The phenol content in glutinous rice was analyzed by taking 1 mL of the extract and putting it in a test tube by adding 1 mL of Folin-Ciocalteu reagent (50%) a mixture of rice extract and reagent and vortexing for 3-4 minutes perpendicularly. Then 1 mL of Na_2CO_3 solution was added. The mixed glutinous rice extract sample was kept for 30 minutes. After 30 minutes, the absorbance of the glutinous rice extract was read using a spectrophotometer at a wavelength of 750 nm.

Determination of antioxidant activity

Determination of DPPH antioxidant activity refers to a modified method (Jiangseubchatveera et al., 2021). A sample of 0.5 mL of glutinous rice extract was placed in 2.5 mL of 0.2 mM 1,1-diphenyl-2-picrylhydrazyl (DPPH) solution in ethanol in a test tube and vortexed perpendicularly. The efficiency of radical capture can be determined by the reduction in the color level of the solution. Absorbance measured with a spectrophotometer at a wavelength of 517 nm was used to measure the antidote effect of the extract for DPPH radicals. Absorbance with a wavelength of 517 nm, decreases as a reaction between free radical scavenger molecules and DPPH radicals. The free radical scavenger activity (RSA) was calculated using the following equation:

$$\text{Free Radical 1Scavenger} = 1 - \frac{\text{Absorbance Sample}}{\text{Absorbance Control}} \quad 100\%$$

Information :
Absorbance control : Absorbance of DPPH solution without sample
Absorbance sample : Absorbance of a sample or standard solution

Total determination anthocyanin

Anthocyanin testing in glutinous rice uses the method Yogaswara et al. (2024), the rice sample was ground, then weighed (2 grams), 8 mL of 0.1% HCl solution in methanol was added. The suspension was ultrasonicated at 25°C for 1 hour. The solution was filtered with Whatman No. 1 filter paper. After that, the sampel was evaporated using a rotary evaporator at a temperature of 30-35°C. The resulting extract was added with 25 ml of methanol, homogenized. The solution was then centrifuged at 6000rpm for 20 minutes. The filtrat (1 ml) was added with 8 ml of buffer pH 1. The sample solution was centrifuged at a speed of 6000rpm. Another sample was prepared by pipetting 1 ml of filtrate and add 8 ml of pH 4,5 buffer. The absorbance of the solution was read at λ 520 nm and 700 nm. Anthocyanin levels in samples were calculated as cyanidin-3-glucoside, by using this formula :

$$Anthocyanin = \frac{A}{\varepsilon x L} \times MW \times DF \times \frac{V}{Wt} \times 100\%$$

Information :
A = (A520nm – A700nm) pH 1.0 - (A520nm – A700nm) pH 4.5
MW = 449.2 g/mol (molecular weight of cyanidin-3- glucoside)
DF = Dilution Factor
e = Koefisien extinction cyanidin-3-glucoside 26900 L/mol/cm
1 = Pathlength (1 cm)
103 = Conversion from grams to mg

Amylose levels

The amylose content test was determined using the method modified from Chatterjee (2018). The determination was based on the iodine binding procedure. Sample (100 mg of crushed rice) was put into

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a test tube then 1 ml of 95% ethanol and 9 ml of 1 N NaOH were added and transferred into a volumetric flask (100 ml). After that, aquadest was added to make up the volume followed by thorough mixing. Five ml of the solution was pipetted into a 100 ml measuring flask, then 1 ml of 1 N acetic acid and 2 ml of Iodine solution were added. Aquadest was added to fill it up to the mark of the measuring flask, shaken, and left at room temperature for 20 minutes. The intensity of the color formed was measured using a spectrophotometer at a wavelength of 625 nm.

Proximate content

Testing of the proximate content of red glutinous rice and black glutinous rice included gravimetric method water, ash and protein contents (micro-Kjeldahl x 6.25), fat content (Soxhlet method), and carbohydrates (By Difference) using the method (Godswill, 2019).

Data analysis

The aroma component data were presented in the form of Table, the chemical composition data for red glutinous rice and black glutinous rice were subjected to analyze of variance (ANOVA), calculated using SPSS 20 program version.

Results and discussion

Compound aroma of red glutinous rice and black glutinous rice

The aroma components of red glutinous rice and black glutinous rice cooked using a rice cooker were presented in Table 1. Table 1 shows that during the processing of glutinous rice a using rice cooker. Aroma compounds identified included hydrocarbon compounds, aldehydes, alcohols, ketones, terpenes, ethers, esters, phenols, carboxylic acids and others. It was noticed that red glutinous rice contained the highest levels of hydrocarbons and aldehydes among other volatile compounds. There were 30 hydrocarbon components, 19 aldehydes, 11 ketones and 8 alcohols. Meanwhile, black glutinous rice identified the highest compounds, namely 22 hydrocarbons, 14 ketones, 18 aldehydes and 7 alcohols. The largest compound found in both samples was from the aliphatic hydrocarbon group, namely tridecane (aliphatic) 13.56%. Tridecane is known as a plant component that has volatile compounds in oil (Li et al., 2024).

Table 1. Results Identification of aroma components of red and black glutinous rice.

No.	Red glutinous rice			black glutinous rice		
	Components	Area	Persen (%)	Components	Area	Persen (%)
			Hydrocarbons			
1	2-Hexenal, (E)-	176437	0.04	Undecane	2624819	0.95
2	Undecane	1303558	0.30	Undecane, 5-methyl-	161730	0.06
3	Dodecane	60677	0.01	Dodecane	141829	0.05
4	2,6-Dimethyldecane	1188482	0.27	Dodecane, 2,6,10-trimethyl-	1297968	0.47
5	2-Hexenal, (E)-	350589	0.08	Undecane, 4-methyl-	334515	0.12
6	Undecane, 4-methyl-	65666	0.02	Decane, 3,8-dimethyl-	438284	0.16
7	Dodecane, 4,6-dimethyl-	273844	0.06	cis-β-Ocimene	811244	0.29
8	Tridecane (alifatik)	58694935	13.56	Tridecane	46762755	16.96
9	Cyclohexene, 1-ethyl-	113120	0.03	Cyclohexene, 1-ethyl-	18375	0.01
10	Decane, 3,8-dimethyl-	718786	0.17	Tetradecane	6544913	2.37
11	Heptylcyclohexane	559895	0.13	3-Eicosene, (E)-	294468	0.11
12	1,3-Hexadiene, 3-ethyl-2-methyl-	3110916	0.72	Cyclopentane, nonyl-	980755	0.36
13	δ-Eiemene	2427762	0.56	Pentadecane	2201261	0.80
14	Cyclotetradecane	1834117	0.42	5,5-Diethyltridecane	652840	0.24
15	Cyclododecane	497952	0.12	Hexadecane	4277193	1.55
16	Pentadecane	2758513	0.64	Toluene	376965	0.14

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17	β-Elemene	904380	0.21	β-Selinene	968799	0.35
18	Caryophyllene	11154760	2.58	Naphthalene	5723980	2.08
19	n-Nonylcyclohexane	363146	0.08	1-Heptadecene	1177089	0.43
20	Hexadecane	7095738	1.64	Octadecane	911714	0.33
21	1-Pentadecene	615709	0.14	Naphthalene, 1,7-dimethyl-	22442	0.01
22	Humulene	628770	0.15	2,6-Diisopropylnaphthalene	30397	0.01
23	γ-Muurolene	227031	0.05	3-Eicosene, (E)-	294468	0.11
24	β-Selinene	610511	0.14			
25	α-Selinene	211838	0.05			
26	α-Muurolene	234341	0.05			
27	Naphthalene (siklik)	12515893	2.89			
28	Heptadecane	613537	0.14			
29	Naphthalene, 2-methyl-	536938	0.12			
30	Naphthalene, 2,7-dimethyl-	88117	0.02			
31	Eicosane	2260654	0.52			
			Ketone			
1	2-Undecanone (alifatik)	7704708	1.78	2-Undecanone	4381190	1.59
2	2-Heptanone	5219061	1.21	2-Heptanone	2582004	0.94
3	5-Hepten-2-one, 6-methyl-	1628333	0.38	2-Nonanone	1021473	0.37
4	2-Nonanone	1005991	0.23	5-Hepten-2-one, 6-methyl-	1139607	0.41
5	3-Octen-2-one, (E)-	3172930	0.73	3-Octen-2-one, (E)-	2231700	0.81
6	2-Decanone	1566790	0.36	2-Decanone	355006	0.13
7	2-Camphanone	767760	0.18	2-Camphanone	914363	0.33
8	Acetophenone (siklik)	136792	0.03	2-Pentadecanone	4277193	1.55
9	2-Tridecanone	168854	0.04	Acetophenone	86213	0.03
10	4-Octen-3-one	18260	0.00	2-Tridecanone	228592	0.08
11	Camphor	69649	0.02	4-Octen-3-one	88990	0.03
12	2-Acetyl-1-pyrroline	871498	0.20	Camphor	35525	0.01
13				γ-Heptanolactone	342300	0.12
14				Benzophenone	275549	0.10
15				2-Acetyl-1-pyrroline	682594	0.25
			Aldehyde			
1	Hexanal (alifatik)	138000008	31.88	Hexanal	87856473	31.87
2	Heptanal	3232806	0.75	Heptanal	1332436	0.48
3	Octanal	12382006	2.86	2,4-Nonadienal, (E,E)-	10034983	3.64
4	2,4-Decadienal, (E,E)-	969128	0.22	2-Hexenal, (E)-	130336	0.05
5	2-Heptenal, (E)-	5737990	1.33	Octanal	4115861	1.49
6	Nonanal	20771352	4.80	2,4-Decadienal, (E,E)-	69872	0.03
7	2-Octenal, (E)-	9449914	2.18	2-Heptenal, (E)-	3516653	1.28
8	Decanal	718648	0.17	Nonanal	8221361	2.98
9	Benzaldehyde	7392854	1.71	2-Octenal, (E)-	3907163	1.42
10	2-Nonenal, (E)-	2667481	0.62	Furfural	138014	0.05
11	2-Decenal, (E)-	1635461	0.38	Decanal	924527	0.34
12	2-Octenal, 2-butyl-	9251280	2.14	Benzaldehyde	3967238	1.44
13	2,4-Nonadienal, (E,E)-	323013	0.07	2-Nonenal, (E)-	1328668	0.48
14	2-Tridecenal, (E)-	975784	0.23	2-Decenal, (E)-	1435721	0.52
15	2-Tridecenal, (E)-	975784	0.23	2-Octenal, 2-butyl-	5431398	1.97
16	Benzaldehyde, 2-methyl (siklik)	156430	0.04	Vanillin	6222	0.00
17	2,4-Decadienal, (E,E)-	147294	0.03	Benzaldehyde, 2-methyl-	399082	0.14
18	Vanillin	701776	0.16			
19	Benzaldehyde, 2-methyl-	154086	0.04			
			Alcohol			
1	2-Dodecanol	114641	0.03	1-Pentanol	4728851	1.72
2	1-Pentanol	6004817	1.39	1-Hexanol	1125834	0.41

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3	1-Hexanol	2085444	0.48	1-Octen-3-ol	10837477	3.93
4	1-Octen-3-ol (alifatik)	25941848	5.99	1-Heptanol	4476884	1.62
5	1-Heptanol	8388342	1.94	1-Dodecanol	1730243	0.63
6	1-Dodecanol	654371	0.15	1-Octanol	5887851	2.14
7	1-Octanol	11184124	2.58	1-Nonanol	1023121	0.37
8	1-Nonanol	1200877	0.28	Linalool	373633	0.14
			Carboxylic Acid			
1	Propanoic acid	3041918	0.70	Benzeneacetic acid (siklik)	1469	0.00
2	Acetic acid	1744051	0.40	Acetic acid	2291699	0.83
3	Butanoic acid	260063	0.06	Butanoic acid	2109326	0.77
4	Octanoic acid	544455	0.13	Propanoic acid	14004	0.01
5	Palmitic acid (alifatik)	3827389	0.88	Dodecanoic acid	135679	0.05
6				Octanoic acid	1107789	0.40
7				Palmitic acid	1570350	0.57
			Esther			
1	2,2,4-Trimethyl-1,3-pentanediol diisobutyrate	213489	0.05	Isobornyl acetate	884353	0.32
2	Isopropyl myristate (alifatik)	335020	0.08	Isopropyl myristate	455691	0.17
3	Methyl palmitate	37418	0.01	Methyl palmitate	335261	0.12
4				Diethyl Phthalate	543469	0.20
			Ether			
1	Furan, 2-pentyl- (siklik)	13505907	3.12	Methyleugenol	2827145	1.03
2	Anethole	914152	0.21			
3	Methyleugenol	753282	0.17			
			Phenol			
1	Phenol, 2-methoxy-	265023	0.06	Phenol, 2-methoxy-	253057	0.09
2	1,2-Benzenediol	5767	0.00	Phenol	47027	0.02
3	Phenol	13377	0.00	3-Allyl-2-methoxyphenol	685295	0.25
3	2-Methoxy-4-vinylphenol	263331	0.06	2-Methoxy-4-vinylphenol	169121	0.06
4	2,4-Di-tert-butylphenol (siklik)	670070	0.15	2,4-Di-tert-butylphenol	556443	0.20
			Terpen			
1	D-Limonene	343029	0,08			
			Other Aromatic Compounds			
1	1H-Indole, 3-methyl-	102666	0.02	Pyrimidine, 4,6-dichloro-	2509455	0.91
2	Benzothiazole	235257	0.05	γ-Heptanolactone	342300	0.12
3				Indole	146118	0.05
	Total Area	432820461	100		275676055	100

Meanwhile, the aliphatic aldehyde group is represented by the hexanal compound, which was found in both samples of red glutinous rice and black glutinous rice. Hexanal, derived from the degradation of linoleic acid, imparts a green and fatty odor, which further enriches the overall aroma profile of green tea (Kun et al., 2025). During processing, 17 aliphatic aldehydes, including hexanal, octanal, nonanal, decanal, (E)-2-nonenal, (E)-2-decenal, and (E, E)-2,4-decadienal, were identified. Aliphatic aldehydes originate from oxidative cleavage and decarboxylation of various fatty acids(Du et al., 2024). At low concentrations, aliphatic aldehydes have a green, grass-like aroma, a quality that might be considered desirable. However, at higher concentrations, aliphatic aldehydes produce a rancid aroma, which is considered unpleasant. According to Hu et al. (2020), aldehyde compounds such as n-nonanal, n-decanal, and (E.)-4-nonenal were identified after cooking rice for 25 minutes.

Bioactive compounds of red glutinous rice and black glutinous rice

Figure 1 shows bioactive compounds of red glutinous rice and black glutinous rice. The total phenol content of red glutinous rice and black glutinous rice after processing using the method rice cooker

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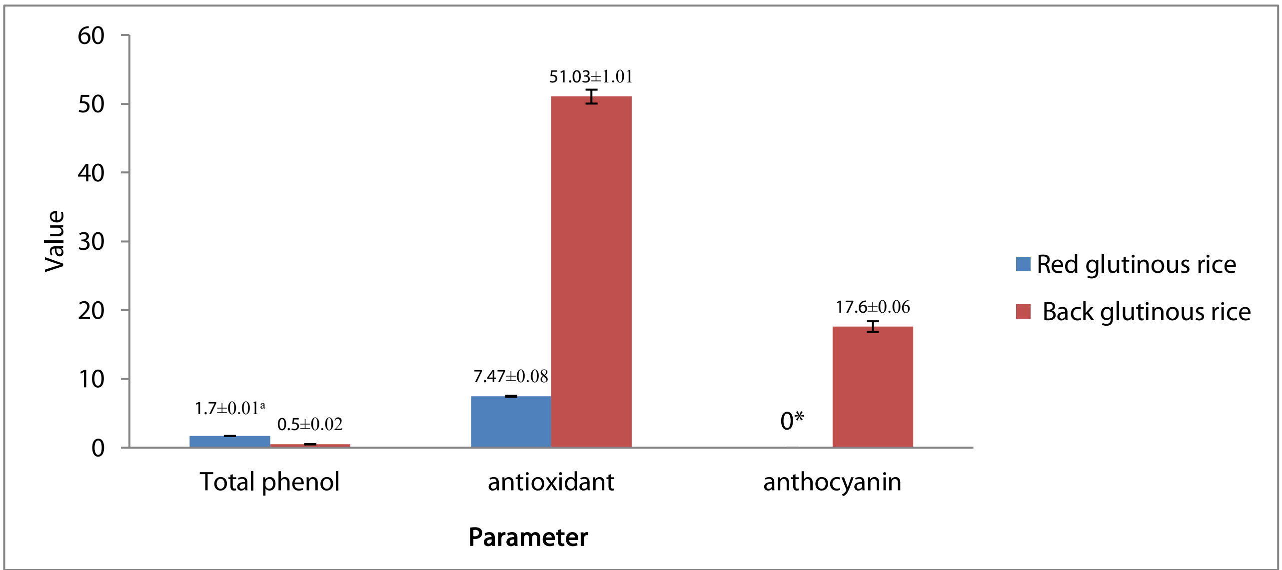
showed that there was a significant difference (P<0.05) in total phenol levels. The results showed that the highest total phenol content was found in red glutinous rice with a value of 1.7 ± 0.01 (mgGAE/g) while black glutinous rice was 0.5 ± 0.02 (mgGAE/g). Cooking process using rise cooker caused a decrease in the phenol content due to degradation of phenol component due to heating. According to Randhir et al. (2008) damage to phenols in buckwheat is caused by heating which results in degradation of phenolic compounds. The total phenol content of black rice was 0.76 ± 0.04 (mgGAE/g) (% db) while the total phenol content of black rice was 0.84 ± 0.06 (mgGAE/g) (Hartati, 2013). Meanwhile, extraction of red glutinous rice has a total phenol content of 10.324 mg GAE/g (Yanti, 2023). This results indicated that the phenol content in red glutinous rice and black glutinous rice was damaged during the cooking process due to high temperatures. Soaking, boiling and steaming significantly affect total phenol content. Han & Baik (2008) also reported that total phenol content and antioxidant capacity decreased up to 80% after cooking.



* Indicates the data is significantly different (p<0.05)

Figure 1. Graph of bioactive compounds and antioxidant capacity of red glutinous rice and black glutinous rice.

The antioxidant capacity (using the DPPH method) of red glutinous rice and black glutinous rice after cooking were 7.4.7±008% and 51.03±1.01%. Based on Table 1 there was a significant difference in DPPH free radical scavenger activity (P<0.05) between the two samples. The highest antioxidant content was found in black glutinous rice. Aluthge et al. (2023) reported that the antioxidant capacity of red blambangan rice before cooking was 34.00 μg/mL and the antioxidant content of black glutinous rice was 66.27%. Based on the results, the total phenol value did not correlate with the antioxidant content of red and black glutinous rice after processing using a rice cooker. This result is different from Aluthge et al. (2023) who reported rice processed using microwave steaming had an antioxidant content of 1.54 ± 0.02% and stated that the highest antioxidant activity was the result of a higher phenolic content. Antioxidants are naturally easily degraded under exposure to different parameters, especially high temperatures during food processing. Thermal degradation of antioxidants greatly inhibits their nutritional value (Ling et al., 2022).

There was no detectable anthocyanin value in red glutinous rice, but black glutinous rice showed an anthocyanin value of 17.60 ± 0.06 mg/100g. Based on Table 1, it can be seen that there is a significant difference in anthocyanin content (P<0.05) between the two samples. Analysis of the anthocyanin content of semi-finished and broken-hull black rice studied by Swasti (2007), had anthocyanin content of 149 ± 11 mg/100g (db) and 152 ± 16 mg/100 g (db). Other research also reported that the anthocyanin content of black rice before heat processing ranged from 52.4 to 126,1 mg/100 g (Arifa et al., 2021). Wojalaka black

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rice anthocyanins 49,11 mg/g, Cempo red rice 7,18 mg/g, Blambangan red rice 6,19 mg/g (Agustin et al., 2021). Based on this data, it is suspected that the anthocyanin value is damaged after cooking. Black glutinous rice has a greater anthocyanin content, namely 17.60mg/100g when compared to red glutinous rice whose anthocyanin levels were not detected after processing (cooking) because the process of processing rice into rice requires higher and longer heat treatment. Thermal degradation of anthocyanins involves hydrolysis of the glycosidic bonds to form alpha. Anthocyanins are known as active compounds that can immediately react with constituents, such as oxygen and light. The significant loss of anthocyanin in glutinous rice is because most of the anthocyanin is in dissolved form located in the vacuoles, especially in the inner bran fraction, which is not conjugated to the cell walls and causes the anthocyanin to be easily lost during the cooking process.

Chemical components of red glutinous rice and black glutinous rice

The result of some chemical content of red glutinous rice and black glutinous rice are presented in Table 2. The amylose contents of red and black glutinous rice cooked using afrom cooking using rise cooker namely 1.18 ± 0.06% and 1.22 ± 0.04%. The two samples did not have significant differences in amylose levels. Previous research revealed that the amylose content of typical Enrekang red rice was 1.22%, Malino rice 15.17%, pinrang bitter melon 1.15% (Masniawati et al., 2013). Red rice and black rice as a result of this research are classified as glutinous rice because they have low amylose content. Rice with low amylose content has very shiny properties, the texture of the rice is soft, slightly wet, very glutinous and the brittleness between the grains is very high so that it absorbs less water and is less fluffy (Luna et al., 2015). Starch granules can expand if they absorb water. Water forms hydrates through hydrogen bonds. The ability to absorb water and expand volume is limited because the starch molecules themselves are linked together via hydrogen bonds. When heated, heat energy can break hydrogen bonds so that the ability of starch to bind water increases and causes the starch to expand larger.

Table 2. Results of some chemical content of red glutinous rice and black glutinous rice

Parameter	Sample mean value	
	Red glutinous rice	Black glutinous rice
Amylose content (%)	1.18 ± 0.06	1.22 ± 0.04
water content (%)	41.17 ± 0.05*	43.47 ± 0.01*
Ash content (%)	0.69 ± 0.01*	0.96 ± 0.02*
Protein (%)	4.84 ± 0.64	4.76 ± 0.03
Fat (%)	1.44 ± 0.03	1.14±0.01
Carbohydrates (%)	51.93 ± 0.06	49.71±0.03

Information: * Indicates that the data is significantly different ($p<0.05$)

Water content is also an important parameter in determining the quality of food ingredients because water content can affect the appearance, texture and taste of food ingredients. The research results show that cooking red glutinous rice and black glutinous rice uses ricecooker showed significantly different results ($p<0,05$). Black glutinous rice has a higher water content, namely 43.47 ± 0.01, than red glutinous rice, 41.17 ± 0,05. The main component of rice is starch and only some of it is pentosan, cellulose, hemicellulose and sugar. Rice starch is around 90% of the dry weight of rice. In the cooking process, starch reacts in water at high temperatures, starch granules absorb water and expand when hot. Water absorption, which is required in the hydration and gelatinization processes, is related to the surface area of the grain per unit weight (Bhattacharya, 2011). The smaller the surface area in that size, indicated by the larger grain size, the more water is needed for cooking (Catur et al., 2020). This process will affect the water content in food.

Ash content is related to the mineral content of a material. The results revealed that the ash content of red glutinous rice and black glutinous rice showed significant differences ($p<0,05$). Red glutinous rice has an ash content of 0.69 ± 0.01 while black glutinous rice has 0.96±0.02. The ash content of black glutinous

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rice shows a higher value when compared to red glutinous rice. Previous research revealed that black glutinous rice contains an ash content of 1.67% (db) (Jiamyangyuen et al., 2019), black Glutinous rice contains 3.60 ± 0.10% (Malik et al., 2022) while red glutinous rice has an ash content of 1.5% (Anggraeni et al., 2018). The ash content is thought to have decreased due to the addition of water during cooking ricecooker which causes the dissolution of inorganic materials due to the addition of water. The process of adding water during the cooking process is thought to reduce the ash content value (Utama et al., 2022).

Protein content of red and black glutinous rice after cooking ricecooker shows values that are not significantly different (p>0,05). The protein values of red and black glutinous rice were 4.84±0,64% and 4.76 ± 0,03% respectively. Rice quality is more influenced by the types of protein glutelin and prolamin than by albumin and globulin because their content is higher. Glutelin is the dominant protein fraction in rice, accounting for 60–80% of the total protein content, and can limit starch swelling through its interaction during heating (Oppong Siaw et al., 2021). This is related to the nature of protein polarity towards water. Rice protein inhibits water absorption and the development of starch granules when rice is cooked, thereby limiting the ability to form optimal gelatinization. The processing process (heating) causes a decrease in protein levels, this can occur because albumin is one of the water-soluble proteins that make up rice, so the decrease in protein levels is caused by loss of albumin protein. Heating can reduce protein levels in rice, this is due to processing with. According to Luo et al. (2020) protein components or their derivatives influence the flavor of rice. Proline as a precursor for the biosynthesis of 2-acetyl-1-pyrroline (2AP) can be formed in the reaction between L-proline and sugar or sugar derivatives which produces aroma components of fragrant rice.

Results of analysis of the fat content of red and black glutinous rice cooked using rise cooker namely 1.44 ± 0,03% and 1.14 ± 0,01%. The two samples did not have a significant difference in fat content (p>0.05). According to Pangerang (2022), the fat content of red rice and black rice, field rice from Bulungan Regency has a fat content ranging from 1.00-2.07% and 0.22-0.88%. The process of reducing fat content can occur during processing. The level of fat damage varies greatly depending on the temperature used and the length of the processing process. The higher the temperature used, the more intense the fat damage that occurs (Malik et al., 2022). The decrease in fat levels can be caused by the destruction of fat globules that occurs due to heating. High fat content in rice can cause a rancid aroma, because fat hydrolysis occurs (by the lipase enzyme) into free fatty acids. At high temperatures, fat will undergo oxidation, decomposition, polymerization, and condensation to produce fatty acids, hydroperoxides, aldehydes, and dimers, trimers, which results in a decrease in food quality (Wang et al., 2023). One of the factors that influences fat content is age and the composition of fatty acids. The older the plant, the more the plant produces fatty acids, where the fat functions as an energy producer (Malik et al., 2022).

Based on the results of carbohydrate calculation of red glutinous rice and black glutinous rice cooked using rise cooker namely 51.93 ± 0.06% and 49.71 ± 0.03%. The two samples did not have significant differences in carbohydrate levels (p>0.05). This data shows that the two samples have similar chemical properties, so the texture of the resulting rice shows no difference. Rice contains carbohydrates consisting of starch amounting to 85-90% of the dry weight of rice, pentose (2.0–2,5%), cellulose, hemicellulose, and sugar (0.6–1.4% of broken rice) (Syahbanu et al., 2023). The heating process also causes a decrease in starch levels. The heating process reduces the carbohydrate and glucose levels in rice. The decrease in carbohydrate content could be caused by starch degradation. Strach degradation may occurs because the glucan double helix structure and crystal structure are disturbed (Liu et al., 2022). In addition, increasing temperature causes damage to starch granules, which results in a change from a crystalline structure to a gel form (Une et al., 2023).

Conclusion

Based on the results of the study, it was shown that red glutinous rice and black glutinous rice processed using a rice cooker were quantitatively found to contain the largest amount of aroma compounds identified as originating from the hydrocarbon group, namely tridecane (aliphatic) 13.56% and 16.96%, aldehydes namely hexanal 31.88% and 31.87% and alcohols namely 1-Octen-3-ol 5.99% and 3.93%. Bioactive compounds in black glutinous rice were identified as having antioxidant capacity of 51.03%, and anthocyanin content of 17.60 mg/100g. These values were higher compared to those of red glutinous rice. The chemical contents, in the form of protein, fat, carbohydrates, and amylose, did not show significant differences between the two samples.

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