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The Effect of Drying Method on Physical and Chemical Characterictic of Porang (*Amorphophallus muelleri Blume*) Chips in North Sumatera Province

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Abstract. Porang is a commodity currently being developed in North Sumatra. Drying is a crucial factor influencing the quality of porang chips, selecting the appropriate drying method can enhance the quality of porang chips. This study reports effect of various drying on the physical and chemical characteristics of porang chips. Porang tuber processed into chips followed a traditional method. Drying treatment include coventional, oven, solar dryer, and greenhouse. The drying rate in the solar dryer was higher compared to other methods (0.18 kg/hour). The results showed a significantly ($p<0.05$) higher yield (18.76 ± 0.21%) in oven than other drying method. The solar dryer exhibited higher ash (8.72 ± 0.06%), proteins (4.69 ± 0.13%), and fats (1.13 ± 0.04%) and lower water (08.53 ± 0.17%), and iron content (3.43 ± 0.01%). Solar dryer showed significantly higher glucomannan (84,42± 0,27%). Person correlation showed significant and positive correlation between ashes and fats, ashes and glucomannans, proteins and ashes, proteins and fats, proteins and glucomannans. This result showed significantly effected of drying method to the physical (yield) and some chemical characteristic of porang chip.

1 Introduction

Porang (*Amorphophallus muelleri Blume*) was identified as one of the priority commodities targeted for development.. In 2019, the porang planting area reached 1,602 hectares, with tuber production at 9,128 tons and chip production reaching 1,553 tons. Porang plants demanded specific growing conditions based on land classification. In the very suitable class (S1), porang thrived in environments with an average daily temperature of 22–30 °C, an annual rainfall of 1200-2000 mm, 1–7 dry months, ample oxygen for good drainage, a fine texture with coarse material <15%, clay CEC value >17 cmol, pH ranging from 5.0–7.0, C-organic >0.4, and a slope <8% [1]. Based on those growing conditions, several areas in North Sumatra were suitable for planting porang.

Porang cultivation took place in North Sumatra Province in 2019. Among the 33 districts in the province, 18 engaged in porang cultivation, with Simalungun Regency having the largest planting area. According to interviews with porang activists in North Sumatra, the

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initial cultivation began in Deli Serdang Regency before spreading to other districts such as Langkat, Serdang Bedagai, Batu Bara, Asahan, Labuhan Batu, Simalungun, Pematang Siantar, Karo, North Tapanuli, Mandailing Natal, Padang Lawas, and South Tapanuli.

The marketing of porang in North Sumatra Province was primarily focused on exports, with China, Vietnam, and Thailand as the main destinations. Export demand for porang tubers was typically for chips, which were thin slices of porang tuber resembling cassava chips that were subsequently dried. The chip-making process began with sortation, where undamaged and properly shaped tubers were separated. This was followed by peeling, washing, and soaking the tubers in water to prevent browning while awaiting further processing. The tubers were then thinly sliced to a thickness of 0.5–1.0 cm and soaked in a 5% salt solution (w/w) at a ratio of 1 kg of tubers to 3 liters of water for 24 hours [2]. The slices were traditionally dried in sunlight under uncontrolled environmental conditions. Quality issues and metal contamination led to the rejection of porang exports, causing a sharp drop in tuber prices, from Rp. 10,000/kg to Rp. 3,500/kg. Preliminary research indicated that the chips produced by farmers had a low yield (below 10%) and a low glucomannan content (under 30%). As a result, this significantly impacted porang cultivation in North Sumatra. Due to market and price uncertainties, some farmers chose to uproot their porang plants and replace them with alternative crops. This shift highlighted the challenges facing the porang industry in North Sumatra, underscoring the need for sustainable practices, market stability, and effective measures to address quality and metal contamination issues to ensure the long-term viability of porang cultivation in the region.

Drying was a crucial stage in the porang chip processing process, as it extended the shelf life and facilitated the transport and distribution of the chips. The drying method used had a significant impact on the final quality of the chips. Several studies have reported the effects of different drying methods on proximate composition [3][4][5], physical properties such as yield and color [6], and chemical properties such as nutritional content and bioactive components [6][5]. The sun-drying method was low-cost and required no special skills, but it had the drawbacks of being unhygienic and highly weather-dependent. Research by [7] showed that sun drying produced the lowest yield compared to other drying methods. ITherefore, improving the quality of porang chips must begin with enhancing the drying process. This research was conducted to assess the effect of different drying methods on the drying rate, as well as the physical and chemical qualities of porang chip.

2 Materials and Methods

1.1 Materials

The main ingredient used was porang tubers harvested in the second period, the weight ranges between 500 to 1000 gramss,ourced from porang farmer partners in Deli Serdang Regency, Binjai City, and Karo Regency. Additional materials included bottled drinking water (AMDK) from PT Aqua, branded salt, and pro-analysis grade chemicals from E-brand and Sigma, which were obtained from PT Brataco Chemica Bogor for chemical analysis. Writing materials were also necessary. The equipment used included a tuber slicer, a solar dryer with a hybrid system [30] a large UV plastic greenhouse with an exit door (owned by SBSN Polbangtan Medan), a disc mill, a sieve, a moisture oven, scales, a blender, a drying oven (Tea Drier Oven, Terada Seisakusho, ED-4K-SP, Shizuoka, Japan), GPS (Global Positioning System), a pH meter, tarpaulins/sheets, a thermometer, compass, stopwatch, camera, computer, and software such as ArcGIS 10.8.

1.2 Prepation

Fresh porang tubers from the second planting period, sourced from farmers in Deli Serdang Regency, Binjai City, and Karo Regency, were sorted to separate healthy tubers from defective or rotten ones. The tubers were characterized by their chemical composition [8]. The moisture content was determined using the oven-drying method, as specified by [8], method number 923.03. Ash content determination was conducted using the direct method, also referring to [8], method number 923.03. The fat content of the samples was analyzed using the acid hydrolysis method, according to [8], method number 922.06. Protein levels were measured using the Kjeldahl method, based on [8], method number 978.04. Total carbohydrate content was calculated using the difference method, while starch content was analyzed using the polarization method, as outlined by [8], method number 945.37. Manganese and iron levels were measured using the Agilent Model 720 Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) method, and microbial levels were determined using the MPN coliform method."

1.3 Chip Porang Processing

The process of producing Porang chips adheres to the standard procedures commonly employed by farmers, initially, the porang tubers are manually peeled using a knife after washing. Subsequently, the tubers undergo thin slicing (2 mm) through the utilization of a specialized tuber slicing machine. A study conducted by [9] revealed that porang tuber slices with a thickness of 2 mm exhibited superior yield and optimal water content in comparison to slices with thicknesses of 1 mm and 3 mm. Following this, 1.5 kg of tuber slices undergo a washing process utilizing 4.5L of pumped water. Post-draining, the tuber slices are soaking d in a 5% w/w salt solution, constituted by dissolving 50 g of salt (PT. Brataco Chemica, Bogor), in 1 L of water for a duration of 1 hour. Subsequently, the tubers are thoroughly rinsed to eliminate any residual salt. The final stage involves subjecting the tubers to the drying process in accordance with the designated treatment.

1.4 Treatment Design

The enhancement of the drying process involved evaluating different drying methods, namely: 1) conventional drying: The materials were placed on bamboo trays and dried under sunlight at temperatures ranging from 30°C to 50°C, 2) oven drying: the materials were dried using an oven at a temperature of 60°C with a humidity level below 10%), 3) solar drying: materials are dried using a solar dryer, which utilizes solar energy to reduce their moisture content. During the drying process, the temperature inside the solar dryer typically ranges from 16.9 to 45.1°C, while the humidity levels between 39.5% and 88.5%), and 4) greenhouse drying: Materials are dried in a greenhouse equipped with UV plastic covering. The greenhouse includes a front door, which facilitates airflow and allows excess heat to exit, ensuring an effective drying process. Temperature range between 40°C to 60°C, the humidity level between 30 to 60 %. Each replicated three times using a completely randomized design.

1.5 Observation Parameters

The drying rate, defined as the mass of water evaporated from the product per unit of time, was calculated using the formula provided by [10]. Physical parameters assessed in this study included yield and color. The yield of porang chips was quantified by measuring the weight of the porang tubers after peeling, as described by [11]. Color evaluation was conducted using organoleptic methods. Chemical parameters included proximate composition, starch, glucomannan, Mn, Mg, and Salmonella contamination. The determination of water content followed the oven-drying method according to [9] standard 923.03. Ash content was determined using the direct method, also referencing [9] number 923.03. Fat content was analyzed using the acid hydrolysis method, as specified by [9] number 922.06. Protein levels were measured using the Kjeldahl method in accordance with [9] number 978.04, with protein content derived by multiplying the nitrogen percentage by a conversion factor of 6.25 for flour. Total carbohydrate content was calculated using the difference method. Glucomannan content was determined using the gravimetric method [12].

Metal contamination analysis, specifically for Fe and Mn levels in the porang chips, was conducted using the Agilent Model 720 Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) method, integrated with the ICP Expert II version 2.0.4 software. Microbial contamination testing followed the Most Probable Number (MPN) coliform method, which involved dilution, mixing with media, homogenization, presumptive testing using McConkey Broth (MCB) media, confirmation testing with Brilliant Green Lactose Bile Broth (BGLB) media, and interpreting MPN number data [13].

1.6 Statistics Analysis

All experiments were conducted with three repetitions. The data acquired from the research underwent processing using Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT). The software utilized for this analysis includes MS Excel and XLSTAT.

2 Results and Discussion

2.1 Characteristic of Porang Tubers from North Sumatra

Porang tubers sourced from farmers in Deli Serdang Regency, Binjai City, and Karo Regency were analyzed to assess their chemical and physical characteristics before treatment. The appearance of these porang tubers is visually depicted in Figure 1, highlighting variations in flesh color. Tubers from Binjai City exhibit a reddish-yellow hue, while those from Karo and Deli Serdang Regencies display a more yellowish color. According to [14] [15], bright yellow is considered typical for porang tuber flesh. Tubers harvested during the second planting period exhibited a darker yellow flesh color compared to those harvested in the first period, with some tubers showing a reddish-yellow hue . In terms of shape, porang tubers from all three districts share a nearly identical oval shape with a depression in the middle, resulting in a symmetrical oval appearance [16].

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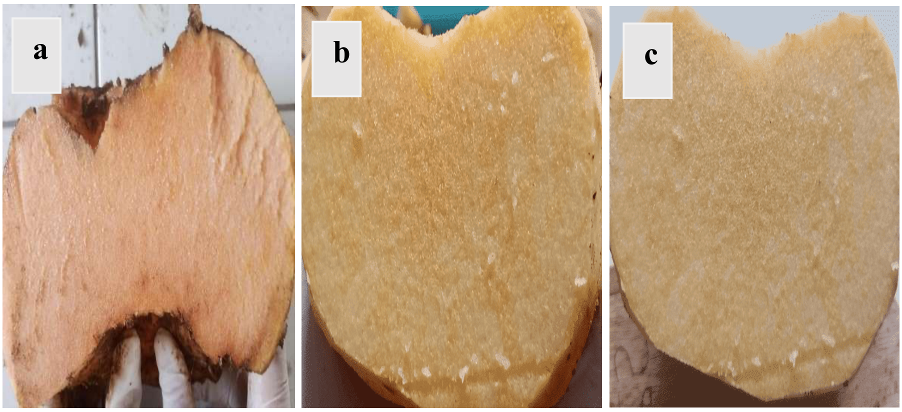

Fig.1. Appearance of porang tubers. a) Binjai, b) Karo, and c) Deli Serdang.

The chemical composition of fresh porang tubers from three districts in North Sumatra Province is presented in Table 1. The fresh porang tubers exhibited a high water content, ranging from 81.88% to 85.69%. [17] also found that Amorphophallus bulbifer tubers had a water content of 84.62 ± 0.23%. High water content can lead to rapid spoilage, necessitating immediate processing, which affects freshness, durability, and microbial growth. Additionally, porang tubers demonstrate low protein content, ranging from 0.85% to 1.26%. This lower protein content aligns with the findings of [18], who reported a protein content of 1.05% in fresh porang tubers. The protein content is comparatively lower than that of Amorphophallus bulbifer cultivated in India [17] or Amorphophallus oncophylus [19], which ranges between 3.15% and 3.26%.

The carbohydrate content in porang tubers ranged from 11.50% to 14.81%, which is lower than the carbohydrate levels found in other typical Indonesian tubers. For instance, suweg and taro tubers exhibit carbohydrate contents of 17.20% and 28.66%, respectively [20]. Carbohydrate levels were calculated using the difference formula based on wet weight, accounting for protein, water, fat, and ash content [21]. When calculated on a dry weight basis, porang tubers reveal substantial carbohydrate content, primarily consisting of starch and other compounds. Additionally, another carbohydrate compound present in porang tubers is glucomannan, a polysaccharide composed of d-mannose linked to β-1,4 d-glucose, with a small amount of acetyl groups [22].

Table 1. The chemical composition of fresh porang tubers from North Sumatra. Values are expressed on wet weight basis.

Chemical Composition	Fresh Porang Tuber from		
	Binjai	Karo	Deli Serdang
Ash content (%)	1,14	1,50	1, 27
Water content (%)	83,09	81,88	85,69
Fat (%)	0,30	0,51	0,21
Proteins (%)	1,26	1,31	0,85
Carbohydrates (%)	14,23	14,81	11,50
Starch (%)	9,80	11,69	9,91
Mangan (Mn) mg/kg	3,37	0,80	1,83
Fe (mg/100 g)	0,58	0,98	1,17
Salmonella	Negative	Negative	Negative

The levels of potentially harmful metal contamination, specifically iron (Fe) and manganese (Mn), were assessed. The iron and manganese content in porang tubers exceeded permitted levels, indicating potential health risks. Elevated iron levels exceeding 1 mg/l can cause irritation to the eyes and skin, while manganese levels below 0.5 mg/l in water are considered safe [23]. The high iron and manganese levels in porang tubers may originate from groundwater, flush water, soil with high iron and manganese content, or pesticide accumulation. Additionally, no biological contamination in the form of Salmonella was detected in porang tubers from all sampling locations.

2.2 The Drying Rate

The objective of this study was to determine the most effective drying method for enhancing or maintaining the quality of porang tubers. Drying times varied for each method: natural drying took 24 hours, oven drying required 16 hours, solar drying took 18 hours, and greenhouse drying lasted 48 hours. The drying duration was determined through visual observation and was stopped when the porang chips became easily breakable[24].

The results indicated that the drying time for the greenhouse method was longer compared to the other methods. For instance, while drying coffee in a greenhouse typically takes 4-8 days to achieve a moisture content of 13% [25] and 3 days to dry Mocaf to a moisture content of 10% [26], the greenhouse method in this study aimed to enhance efficiency and quality while overcoming obstacles encountered during sun drying [27]. The greenhouse utilized a UV plastic cover and featured a front door to facilitate air circulation, thereby maintaining the necessary temperature and humidity for effective drying [27].

Generally, drying in a greenhouse proves to be more effective than conventional direct sunlight drying, which typically takes twice as long as greenhouse drying [25]. However, in this study, the conventional drying time using direct sunlight was shorter than the greenhouse method, possibly due to unstable air humidity within the greenhouse affecting the overall drying process. The drying speed in a greenhouse is influenced by factors such as air temperature, pressure, humidity, and airflow speed [27]. Fluctuations in temperature distribution within the greenhouse can impact the optimal release of water during the drying process

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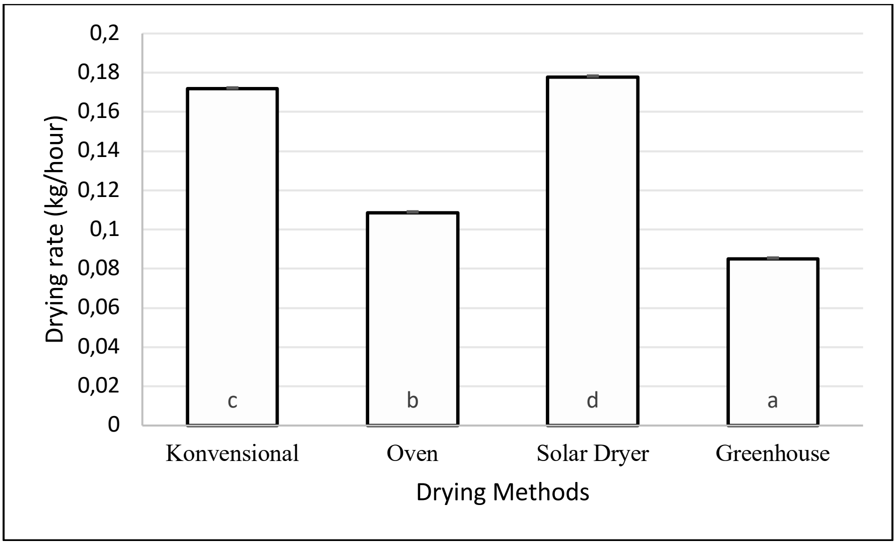

Fig 2. A drying rate in various drying methods. Value with different notation has a significant difference at 5% (LSD test)

A solar dryer proved to be more efficient and less time-consuming compared to other drying methods. The solar collector and collector device plates on the solar dryer were effective in absorbing more heat, thereby enhancing the drying process [28]. Solar dryers offer several advantages over natural drying, including reduced energy consumption, shorter drying times, and improved product quality [29].

The solar dryer used in this study had specific dimensions and was equipped with a solar collector, blower, and photovoltaic panels. Additionally, desiccants were incorporated to absorb moist air until equilibrium was reached [30]. During the drying process, the temperature in the solar dryer ranged from 16.9 to 45.1 ºC, while humidity levels fluctuated between 39.5% and 88.5%.

The drying rate, defined as the mass of water evaporating from the product per unit time, was compared across various drying methods (see Figure 2). The findings indicated that the drying rate in the solar dryer was higher than in other methods, specifically at 0.18 kg/hour. In contrast, the drying rate in the greenhouse was slower, at 0.08 kg/hour. This discrepancy compared to the research by [29], which reported a faster drying rate in a drying house, may be attributed to differences in the efficiency of drying equipment [31]. Additionally, the thickness of the tuber and the amount of material being dried could influence the drying rate, with thicker layers and larger quantities potentially slowing down the process [29] [31] [10].

2.3 The Effect of Drying Methods to Physical Characteristic of Porang Chips

The organoleptic observation of porang chip color revealed a consistent brownish-yellow hue across all treatments. According to [32], this change indicates a reduction in brightness due to the drying process. In contrast, previous studies [9] [33] found that unconventional drying methods, such as the greenhouse effect and tray drying, produced brighter product colors compared to sun drying. The color changes during drying are attributed to the carbohydrate and protein content in the tubers, as elevated temperatures can trigger browning reactions due to the interaction of carbonyl and amine groups [34]. Additionally, the browning process of porang chips is influenced by phenolic compounds, such as tannins, and polyphenol oxidase (PPO) enzymes [35].

Statistical analysis indicated a significant impact of the drying method on porang chip yield ($p < 0.05$). The yield for oven-dried porang chips was significantly higher (18.76 ± 0.21%) than that of other drying methods, followed by conventional drying (15.90 ± 0.07%). In contrast, the greenhouse drying method resulted in a lower yield (15.42 ± 0.09%) as presented in Table 2. This difference may be attributed to variations in drying time, with oven drying requiring a shorter duration of 16 hours. Generally, longer drying times tend to result in lower yields [36]. However, this trend did not hold true for drying using a solar dryer and greenhouse methods. The final water content of porang chips dried in the greenhouse was 10.50 ± 0.23%. Variability in product yield is closely linked to the water content of the material [37].

2.4 The Effect of Drying Methods to Chemical Characteristic of Porang Chips

The chemical composition of porang chips produced through different drying treatments is presented in Table 2. The water content varied significantly among different drying method. The value of water content in order to: solar dryer < oven < conventional < greenhouse. Suggesting significant effect of drying methods on water content. The low water content contributes to extended storage duration by mitigating microbial growth and preserving chip integrity during storage. A solar dryer produced porang chips with the lowest water content compared to other drying techniques. The drying process is influenced by factors such as humidity, air flow rate, and the initial water content of the material [38]. Although the drying treatments involved the same material with identical initial water content, variations in humidity, temperature, and air flow rate were observed across each treatment. The hybrid solar dryer type, for instance, has demonstrated a drying rate of 0.4 kg/hour at a 10 kg load, an average temperature of 43.35 ºC, and an average humidity of 42.6% [29]. Additionally, the solar dryer is equipped with a heat capture device, ensuring effective drying of porang tubers even in less favorable weather conditions. This capability aids in removing water bound to the material, resulting in a low water content. Similar outcomes are observed with drying oven systems, where a stable temperature of 70 ºC is maintained throughout the drying process, ensuring consistent drying. Conversely, conventional and greenhouse drying treatments rely heavily

The ash content is linked to the compound content present in the material. The ash contents varied significantly among different drying methods, ranging from 7.76 ± 0.08 (%) to 8.72 ± 0.06 (%), respectively in the order of greenhouse < oven < conventional < solar dryer. Similarly, [39] had reported a higher ash content for Turkey Berry drying using a greenhouse compared to other drying methods. The results show a decrease of ash content compare to the fresh tuber. It could be attributed to the potential loss of minerals or compounds, possibly occurring during the washing process. The protein content varied significantly among drying methods, ranging from 3.85 ± 0.08 (%) to 4.69 ± 0.13 (%). The order of protein content from lowest to highest is observed as follows: oven < greenhouse < conventional < solar dryer drying method. The effect of different drying methods on nutritional components have been reported by [3][4][5]. Notably, the solar dryer method had the highest protein content. The statistical analysis results indicate that there is no significant difference in fat and carbohydrates content among drying treatments ($p > 0.05$). The fat content value ranged from 0.63 ± 0.01 (%) to 1.13 ± 0.04 (%), Carbohydrate content (%) is in the range 76.49 ± 0.27 (%) to 78.07 ± 0.21(%), in the order of carbohydrate content using conventional drying treatments < greenhouse < solar dryer < oven.

Table 2. Yield, Proximate composition, Mg, Fe and Salmonella contamination of Porang Chip using different drying methods. Values are expressed on dry weight basis.

Drying Methods	Yield (%)	Ash (%)	Water (%)	Fat (%)	Proteins (%)	Carbohy-drates (%)	Mg (kg/)	Fe	Salmonella
Konventional	15.98 ± 0.07 b	08.36 ± 0.06^{b}	10.00 ± 0.08^{bc}	00.69 ± 0.02^{a}	04.48 ± 0.11^{bc}	76.49 ± 0.27^{a}	08.68 ± 0.18^{b}	09.74 ± 0.23^{c}	Negative
Oven	18.76 ± 0.21 c	07.88 ± 0.10^{a}	09.57 ± 0.21^{b}	00.64 ± 0.02^{a}	03.85 ± 0.08^{a}	78.07 ± 0.21^{b}	10.24 ± 0.04^{c}	12.79 ± 0.04^{d}	Negative
Solar Dryer	15.42 ± 0.09 a	08.72 ± 0.06^{c}	08.53 ± 0.17^{a}	01.13 ± 0.04^{b}	04.69 ± 0.13^{c}	76.94 ± 0.05^{a}	08.78 ± 0.05^{b}	03.43 ± 0.01^{a}	Negative
Greenhouse	15.42 ± 0.05 a	07.76 ± 0.08^{a}	10.50 ± 0.23^{c}	0.63 ± 0.01^{a}	04.23 ± 0.11^{b}	76.89 ± 0.03^{a}	7.45 ± 0.01^{a}	5.64 ± 0.01^{b}	Negative

A mean value followed by the same letter was not significantly different according to the LSD Advanced Test at a significance level of 0.05.

The manganese content of porang chips exhibited significant differences between conventional and oven drying treatments ($p < 0.05$), while no significant difference was observed between conventional and solar dryer treatments ($p > 0.05$). In contrast, the iron content demonstrated significant differences among all drying treatments ($p < 0.05$), with the highest iron content found in the oven-dried samples (12.79 ± 0.04 mg/100 g). Notably, SNI number 7939:2020 does not specify minimum manganese and iron content requirements for porang flakes. However, an interview with the Belawan Quarantine Agency of North Sumatra Province indicated that the rejection of North Sumatra porang chips for export was partly attributed to elevated iron levels. The original manganese content in porang tubers before drying was 1.83 mg/kg, while the iron content was 1.17 mg/100 g. After drying, there was a significant increase in both manganese and iron levels in the porang chips.

Figure 3 presents the starch and glucomannan levels of porang chips under various drying treatments. Statistical analysis revealed a significant effect of drying method on both glucomannan and starch content ($p < 0.05$). Specifically, the results showed a notable difference in glucomannan content between drying methods. The solar dryer yielded the highest glucomannan content (84.42 ± 0.27), while the oven-dried samples exhibited the lowest (69.80 ± 0.01). Porang tubers from Deli Serdang Regency, classified as yellow porang (Amorphophallus muelleri), contained exceptionally high glucomannan levels, surpassing those from Sulawesi, which had levels of 39.29 ± 1.855% [40].

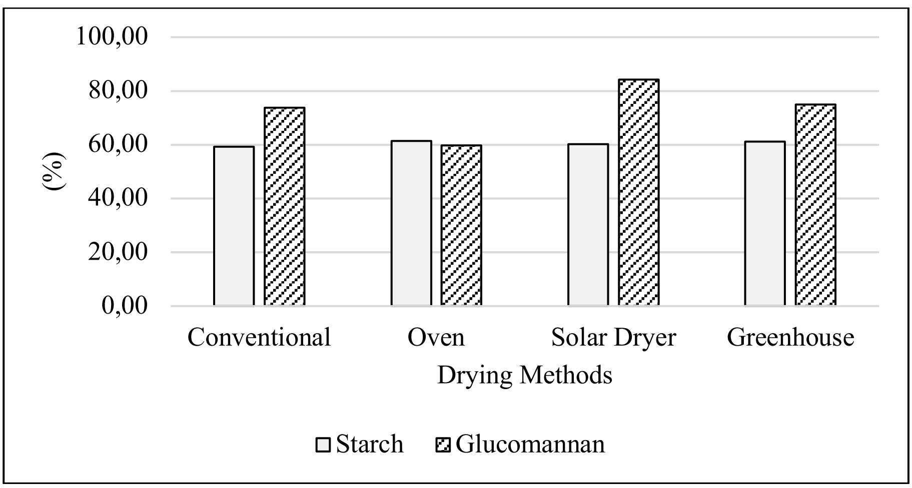

Fig 3. Starch and glocomannan content of Porang chip.

In this study, the initial glucomannan content of porang tubers was not analyzed; however, literature indicates that porang tubers of the Amorphophallus muelleri variety contain glucomannan levels of approximately 3.58%. The drying process using a solar dryer significantly increased the glucomannan content, enhancing it by nearly 23 times. This increase is attributed to the lower and more stable drying temperatures maintained in the solar dryer compared to greenhouse and conventional drying methods. According to [41], glucomannan can decompose at drying temperatures exceeding 60 °C. This finding also explains the observed decrease in glucomannan levels during oven drying, where the temperature of 70 °C leads to considerable decomposition of glucomannan.

3 Conclusion

Porang tubers sourced from three districts in North Sumatra exhibited high water content alongside lower levels of protein, fat, ash, and carbohydrates. Among the drying methods assessed, the solar dryer demonstrated the fastest drying rate compared to the others. Regardless of the method employed, porang chips consistently displayed a brownish-yellow color. Statistical analysis revealed a significant effect of the drying method on porang chip yield ($p < 0.05$). The proximate composition varied significantly across different drying methods ($p < 0.05$), except for the fat and carbohydrate content, which remained relatively stable. Additionally, notable increases in manganese and iron levels were observed in the porang chips during the drying process. The drying method also significantly influenced the glucomannan and starch content ($p < 0.05$), with the solar dryer yielding the highest glucomannan content.

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