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Effect of drying conditions on the phytochemicals and qualities of herbal tea made from the silk and cobs of red sweet corn

Phornpan Ji-u[1] and Tarit Apisittiwong[2]*

[1]Program of Food Science and Technology, Faculty of Agricultural Technology and Industrial Technology, Nakhon Sawan Rajabhat University, Nakhon Sawan 60000, Thailand
[2]Faculty of Food Technology, College of Agricultural Innovation and Food Technology, Rangsit University, Pathumthani 12000, Thailand

*Corresponding author; E-mail: tarit.a@rsu.ac.th

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Abstract

This research investigated suitable hot air drying conditions to prepare corn silk and cob herbal tea from the silk and cobs of the red sweet corn “Siam Ruby Queen”. The optimum process conditions and quality of the tea were determined. The drying was performed at four different temperatures: sun drying (37±3), 60, 70, and 80 °C. The optimum drying conditions were 70 °C, 1 h and 70 °C, 5 h for the corn silk and the corn cob, respectively. The herbal tea contained 43.10±2.26 mg/100 g total anthocyanin content, 14.44±0.78 mg/100 g of cyanidin, 28.66±0.74 mg/100 g of peonidin, and 990.11±39.49 mg GAE/100 g total phenolic content. The color values of the infusions, L*, a*, and b*, were 25.53±0.04, 31.50±0.08, and 30.67±0.33, respectively. The moisture content and water activity of the product were 5.7725±0.7407% and 0.3152±0.0760. There was no contamination by yeasts or molds, including *Escherichia coli*, in the product. Therefore, the corn silk and cob herbal tea developed in this study met the Thai community products standard (TCPS 478/2562).

Keywords: *anthocyanins content; corn silk and cobs; hot air dryer; infusion tea; sun drying; total phenolic content.*

1. Introduction

Herbal teas are made from blends of dried plant parts, including leaves, grasses, flowers, fruits, nuts, seeds, and barks. One main herbal ingredient or a mixture of many herbal ingredients may be used to make a herbal tea to achieve a certain beneficial effect (Ravikumar, 2014). The beneficial effect of herbal teas is attributed to their phytochemicals. These compounds may help reduce the risk factors for non-communicable diseases (NCDs) and hence, the management of NCDs (Chandrasekara & Shahidi, 2018). Anthocyanins are a well-known group of phytochemicals with exceptional properties, including nutritional value, promotion of healthy functioning, and other pharmacological characteristics.

Anthocyanins are flavonoid compounds that impart vibrant red, blue, and purple colors to fruits, vegetables, some cereals, seeds, and plant leaves (Bendokas et al., 2020). Several studies have reported that anthocyanins show various biological activities, particularly antioxidant, antidiabetic, anti-obesity, anti-glycation, and hypoglycemic activities (Chaiittianan, Sutthanut, & Rattanathongkom, 2017; Senphan, 2019; Ferron, Colombo, Mannucci, & Papetti, 2020). The antioxidative and anti-inflammatory actions of anthocyanins have been reported to improve recovery from exercise. Positive effects on blood flow, metabolic pathways, and peripheral muscle fatigue, or a combination of all three, may be responsible for enhancing exercise performance after consuming anthocyanin (Cook & Willems, 2019). Moreover, in a recent review of the dietary effects of anthocyanins on human health, Gonçalves, Nunes, Falcão, Alves, and Silva (2021) have suggested that the regular consumption of anthocyanins offers many health benefits because anthocyanins can reduce the amount of free radicals, reactive species, and pro-inflammatory makers. Anthocyanins can reduce oxidative stress levels, avoid inflammatory processes development, keep human organs and cell components safe from damage, and thus confer distinct levels of protection. Therefore, finding raw materials that are cheap, available, and high in anthocyanins content is of great importance.

Colored corn is one raw material containing high amounts of anthocyanin, especially in the silk and cob. These parts of the corn are considered an agricultural waste product following harvesting. Many studies have found that parts of the red or purple corn, such as kernels, cobs, silk, and husks, are rich in anthocyanins and phenolic compounds (Harakotr, Suriharn, Tangwongchai, Scott, & Lertrat, 2014; Simla, Boontang, & Harakotr, 2016). Differences in molecular structures and contents lead to many colors, from pink to dark blue, which characterize the different pigmented corn varieties (Colombo, Ferron, & Papetti, 2021). According to previous studies of purple corn, the total anthocyanin content in the cob was higher than that of the kernel, and the total anthocyanin level of the husk ranged from 17.3% to 18.9% of the dry weight of the ear, roughly ten times higher than that of the kernel, which was only 1.78% (Yang & Zhai, 2010; Li et al., 2008). For purple waxy corn waste, the silk had the greatest total phenolic content and, thus, the highest antioxidant activity, while the cob contained the highest total anthocyanin content (Kapcum et al., 2021). The presence of these phytochemicals and the high antioxidant potential of the kernels, including the cob and silk of red or purple corn, makes them valuable ingredients in healthy and functional food and beverages.

As for corn silk (*Zea mays* L.), Žilić, Janković, Basić, Vančetović, and Maksimović (2016) have indicated that corn silk harvested at the silking stage can be a natural source of phenolic compounds because their total phenolic and flavonoid contents were 1.2 to 2.6 times higher than that of some medicinal herbs. Moreover, the blood sugar level of consumers with high blood sugar levels was reduced when they regularly drank corn silk tea due to the ability of flavonoid compounds to stimulate insulin activation (Shalihah, Pamela, & Kusumasari, 2020). Li et al. (2019) have shown that the boiling water extract of corn silk had an anti-hypertension effect in rats via the inhibition of ACE, the target of anti-hypertensive drugs, and concluded that corn silk tea is an herbal medicine with low toxicity. Wattanathorn, Thukham-mee, Muchimapura, & Kirisattayakul (2020) have also demonstrated that memory, the status of oxidative stress, and cholinergic and monoaminergic system functions of the hippocampus are improved by corn cob herbal tea.

Most crops are easily affected by microbial spoilage, which shortens their shelf-life and increases postharvest losses, mainly due to their high moisture content (80%–90% wet basis). Drying is a reliable and efficient method for preserving perishable food and agricultural products. It also reduces the volume and weight for ease of storage and transportation. The removal of water during drying can decrease moisture-induced degradation, chemical reactions, and enzymatic activities of the products (Baysal, Icier, Ersus, & Yildiz, 2003). Fruits, vegetables, and aromatic herbs can be dehydrated using various drying techniques. The most relevant methods include convective air drying, spray drying, and freeze-drying, while other methods are microwave, infrared, or combination drying (Calín-Sánchez et al., 2020). The most important factor in controlling the whole drying process and the quality of the finished product is the source of power. The composition of the agricultural products should be used to choose an appropriate drying technique (Lee et al., 2016).

Hot air or convective air drying is the most commonly employed commercial technique for drying agricultural products because of its ease of operation and low cost, suitable for community enterprise businesses. The moisture removal mechanism when drying with hot air starts when the ambient heat transfers to the surface of the food by convection, then through the structure of the food by conduction. Finally, the water diffuses from the interior parts of the food to the interface between the air and food. The water also joins a hot stream of air from the interface by convection (Demiray & Tulek, 2017).

The assessment of the phytochemical contents of five medicinal plants under three different drying methods by Gamage et al. (2021) has revealed that a solar dryer would be an economical, efficient, and effective drying method for preserving bioactive compounds contained in medicinal plant leaves; however, optimizing the solar drying method is critical to improving the quality of the dried products. The drying behavior of *Rosa pimpinellifolia* fruits has been used to formulate a new tea variety. Using a cabinet dryer revealed that the dehydration rate increased at 70–90 °C (Pashazadeh, Zannou, & Koca, 2020). Previous research has revealed that drying, an important heat process for making herbal teas, may cause a significant loss of bioactive compounds and consequently decrease the product quality and health benefits (Mbondo, Owino, Ambuko, & Sila, 2018; Gasecka et al., 2020). Using a hot-air drying oven at 80 °C to make herbal tea from Roselle (*Hibiscus sabdariffa* L.) flowers had the highest retention of total phenolic content and antioxidant capacity (Nguyen & Chuyen, 2020). Anthocyanins are readily degraded during thermal processing, which affects their color and functional properties. The magnitude and duration of heating directly influence the stability of the anthocyanins. Some unexpected and undesirable chemical reactions that indirectly affect food quality can occur when heat processing at 50 °C or higher is used (Patras, Brunton, O'Donnell, & Tiwari, 2010). Charmongkolpradit, Somboon, Phatchana, Sang-aron, and Thanwanichkul. (2021) have studied the drying of purple waxy corn kernel using a tunnel dryer and indicated the highest total anthocyanin content was obtained at 65 °C.

"Siam Ruby Queen" is a red super-sweet sweet corn hybrid variety grown in Thailand. It is the first red super-sweet sweet corn in the world. This corn can be eaten raw when fresh and tastes super sweet and crisp. In community enterprises, many parts of Siam Ruby Queen corn are processed into many healthy products, such as corn milk, corn paste chili sauce, crispy corn chip, and herbal tea in bags. Developing these products made from red sweet corn would indirectly provide economic benefits to the community and small-scale industries. There is not enough information about the bioactive compounds and qualities of this corn or how they are influenced by different drying processes. Therefore, this research optimized the drying conditions to obtain the highest quality product from Siam Ruby Queen corn.

2. Objectives

To investigate suitable drying conditions of corn silk and cobs using hot air drying to prepare corn silk and cob herbal tea and increase the total anthocyanin and phenolic content of the product.

3. Materials and methods

3.1 Raw materials

Kernels, silks, and cobs of "Siam Ruby Queen" corn harvested from Nuttaya Cornfield, Tha Tako district, Nakhon Sawan Province, Thailand. The corn was harvested 60 days after planting.

3.2 Chemicals and reagents

Anthocyanin standards, including cyanidin-3-glucoside chloride and peonidine-3-glucoside chloride, as well as gallic acid and Folin–Ciocalteu phenol reagent, were purchased from Sigma (St. Louis, MO, USA). All HPLC-grade solvents were purchased from Fisher (Pittsburgh, PA, USA). All other chemicals were analytical grade.

3.3 Drying process

The corn cobs and silk were dried using a hot air dryer (OFM 1997, Thailand) according to the conditions described for each treatment below. The dried samples were separately vacuum-packed in aluminum foil bags for further analysis. Corn kernels were roasted at a low temperature for 20 minutes and then dried in a hot air dryer at 70 °C for approximately 5 hours until their moisture content was below 10%, following the roasting method of the community enterprise. The dried kernels were also vacuum-packed in an aluminum foil bag for use in the corn silk and cob tea.

3.4 Effect of drying conditions on moisture content and water activity of corn cobs and silk

The corn cobs were dried as whole cobs according to the method used by the community enterprise. However, a preliminary study showed that preparing the corn cobs by chopping them into pieces (1.5–2 cm long) significantly accelerated the reduction of their moisture content and water activity (a_w) when compared to whole cobs. In addition, after drying for 5 hours, the moisture content of the chopped corn cobs was six times lower than that of the whole corn cobs (data not shown).

Thus, in this study, the corn silk was spread in a layer 1.5–2 cm thick on the tray of the hot air dryer, and the corn cobs were chopped into 1.5–2 cm pieces before drying. The drying process was carried out at 60, 70, and 80 °C and compared to the conventional process, sun drying. The samples were dried until their moisture contents were below 10% (according to the standard TCPS 478/2562). The moisture content and a_w of samples were analyzed every 1 hour during the drying process. The moisture content (% wet basis, wb) was analyzed according to the standard method (AOAC, 2000), and a_w was measured using a water activity meter (AQUALAB 3, METER Group, Pullman, WA, USA).

3.5 Preparation of the corn silk and cob herbal tea

The corn silk and cobs were dried under different conditions (sun drying, 60, 70, 80 °C), which had a moisture content of less than10% were chosen to prepare the corn silk and cob herbal tea. Each ingredient was coarsely ground using a herbal grinding machine. The ground silk, cobs, and kernels were mixed at the ratio of 0.32 to 1.28 to 1. Then, 2.6 g of the mixture was packed in a corn fiber tea bag. All the tea bags were packed in an aluminum foil zip lock bag to protect them from light and were kept at room temperature before further analysis.

3.6 Physical, chemical, and microbiological qualities of the corn silk and cob herbal tea

3.6.1 Determination of water content and a_w

The moisture content of the tea was measured according to the standard method (AOAC, 2000), and a_w was measured using the same water activity meter as above.

3.6.2 Color measurement of infused tea

Sample tea bags from each drying condition were placed in cups, and 150 ml of hot water (100 °C) was added. The tea bags were allowed to infuse for 10 minutes. The bags were then removed from the infusion. After cooling down, samples of the infusion were placed in a specific bottle for color measurement. The L^*, a^*, and b^* values were measured using a colorimeter (ColorQuest XE, Hunter Lab, Reston, VA, USA).

3.6.3 Analysis of total anthocyanin and total phenolic contents

In this study, acid hydrolysis and HPLC were used to determine the anthocyanin content of the corn silk and cob herbal tea samples obtained from different drying conditions according to Zhang, Kou, Fugal, and McLaughlin (2004). The total anthocyanin content was calculated from the sum of the cyanidin and peonidin and reported as mg/100 g (wet basis, wb). Briefly, 10 g of ground samples were extracted by sonication in 100 ml of 1:1 water:methanol solution containing 2% HCl for 20 minutes. A portion of each sample solution (~3 ml) was filtered through a 0.45 m PTFE filter and hydrolyzed at 100 °C for 60 minutes. The hydrolyzed samples were immediately cooled to room temperature for HPLC analysis. HPLC analyses were conducted on a Hewlett-Packard 1090 HPLC-DAD instrument with an ODS column (5-µm particle size, 4.6 i.d. × 250 mm). An aqueous solution containing 0.4% TFA in acetonitrile was used as the eluent. Other chromatographic conditions were as follows: injection volume, 20 µl; flow rate, 1 ml/min; column temperature, 35 °C; and the detection wavelength was 530 nm.

The total phenolic content was determined by the modified method of Lu et al. (2007). The samples were extracted with dimethylformamide (DMF):0.1 N acetate buffer (1:1, v/v) by sonication (40 kHz, 120 W). Then, the total phenolic contents of the extracts were assayed based on the colorimetric oxidation/reduction method using Folin–Ciocalteu phenol reagent. The absorbance of the sample was measured at 760 nm and was compared to the standard curve of a gallic acid solution. The total phenolic content was expressed as milligrams of gallic acid equivalents (mg GAE/ 100 g, wb).

3.6.4 Microbiological analysis

The corn silk and cob herbal teas from different drying conditions were assessed for microbiological qualities. The aerobic plate count (APC) was used to calculate the total microbial level, including bacteria, yeasts, and molds, in CFU/g (AOAC, 2000). *Escherichia coli* was determined using Petrifilm™.

4. Statistical analysis

Experiments were run in triplicate using three different sets of samples. The data are presented as mean ± standard deviation. An analysis of variance (ANOVA) was calculated for each parameter from the completely randomized experimental design using statistical software (SPSS 11 for Windows, SPSS Inc., USA). Differences between values were considered significant at $p < 0.05$ using Duncan's new multiple range test (DMRT).

5. Results and discussion

5.1 Effect of drying conditions on the moisture content and a_w of corn cobs and silk

The effect of drying temperature and duration of different drying conditions on the moisture content and a_w of corn silk is shown in Tables 1 and 2, and the effect on corn cobs is shown in Tables 3 and 4. Decreased moisture content and a_w at different drying temperatures as a function of time were observed. The final moisture content of the raw materials should be below 10%, as specified in TCPS 2562/,478 and the targeted a_w of the dried products was 0.6, the general limits for the growth of yeasts, molds, and bacteria (Shi et al., 2008). The moisture content of the corn silk was higher than that of the corn cobs. Similarly to this study, the moisture content of the silk from mature corn has previously been reported to be 84.42%, decreasing to 3.95% after drying at 55 °C for 2 days (Rahman & Rosli, 2014). Another study by Senphan (2019) has indicated the high moisture content of corn silk from sweet and purple waxy corn at 89.14%–89.57%.

As can be seen from the drying times, the water in the corn silk and cobs evaporated faster during hot air drying than during sun drying. This is because the temperature in the hot air drier is controlled; the hot air continuously passes through the foods and exits from the drier during the process. In contrast, the temperature varies during sun drying. Although sun drying has the advantage of requiring less energy and reducing the production cost, it has many drawbacks. Sun drying is strongly susceptible to weather conditions, and it exposes the foods to possible sources of hazardous contamination (e.g., insects, birds, and other animals). Hence, sanitation is compromised when using this method.

Table 1 Moisture content (% wb) of corn silk dried at different temperatures

Duration (hours)	Temperature (°C)			
	37 ± 3 (sun drying)	60	70	80
0	84.4970 ± 0.0032^{d}	84.4970 ± 0.0032^{c}	84.4970 ± 0.0032^{f}	84.4970 ± 0.0032^{e}
1	61.6246 ± 1.7668^{c}	34.6881 ± 4.2846^{b}	6.9559 ± 0.0259^{e}	6.8472 ± 0.0689^{d}
2	16.0570 ± 3.2787^{b}	5.6533 ± 0.0245^{a}	4.8501 ± 0.0200^{d}	4.2660 ± 0.1812^{c}
3	6.5065 ± 0.2573^{a}	5.4547 ± 0.0579^{a}	4.3035 ± 0.1039^{c}	4.1905 ± 0.0284^{c}
4	6.4648 ± 0.0865^{a}	5.4006 ± 0.0880^{a}	4.1999 ± 0.1083^{c}	4.1241 ± 0.0062^{c}
5	6.3225 ± 0.2094^{a}	5.0965 ± 0.0124^{a}	4.1403 ± 0.2517^{bc}	3.6482 ± 0.5018^{b}
6	6.3174 ± 0.0569^{a}	5.0958 ± 0.1056^{a}	4.1211 ± 0.5506^{bc}	3.3902 ± 0.1894^{ab}
7	6.3023 ± 0.0147^{a}	4.8955 ± 0.1005^{a}	3.6518 ± 0.0138^{ab}	3.3025 ± 0.1742^{ab}
8	6.2141 ± 0.1694^{a}	4.8593 ± 0.0437^{a}	3.4515 ± 0.1795^{a}	3.0796 ± 0.0132^{a}

Means with different letters in the same column were significantly different at $p < 0.05$

Table 2 The water activity (a_w) of corn silk dried at different temperatures

Duration (hours)	Temperature (°C)			
	37 ± 3 (sun drying)	60	70	80
0	0.9935 ± 0.0021^{c}	0.9935 ± 0.0021^{e}	0.9935 ± 0.0021^{e}	0.9935 ± 0.0021^{g}
1	0.9800 ± 0.0057^{c}	0.9260 ± 0.0396^{d}	0.4600 ± 0.0552^{d}	0.4265 ± 0.0191^{f}
2	0.5330 ± 0.0141^{b}	0.3270 ± 0.0113^{c}	0.3445 ± 0.0035^{c}	0.3435 ± 0.0007^{e}
3	0.2420 ± 0.0170^{a}	0.2540 ± 0.0028^{b}	0.2500 ± 0.0070^{b}	0.2310 ± 0.0127^{d}
4	0.2385 ± 0.0092^{a}	0.2195 ± 0.0120^{a}	0.2107 ± 0.0014^{ab}	0.2080 ± 0.0042^{c}
5	0.2265 ± 0.0021^{a}	0.2160 ± 0.0057^{a}	0.2045 ± 0.0035^{a}	0.1870 ± 0.0014^{b}
6	0.2255 ± 0.0007^{a}	0.2150 ± 0.0014^{a}	0.2045 ± 0.0007^{a}	0.1760 ± 0.0028^{b}
7	0.2290 ± 0.0057^{a}	0.2070 ± 0.0028^{a}	0.2035 ± 0.0021^{a}	0.1675 ± 0.0049^{ab}
8	0.2265 ± 0.0035^{a}	0.1890 ± 0.0085^{a}	0.1720 ± 0.0028^{a}	0.1530 ± 0.0071^{a}

Means with different letters in the same column were significantly different at $p < 0.05$

Table 3 Moisture content (% wb) of corn cobs dried at different temperatures

Duration (hours)	Temperature (°C)			
	37 ± 3 (sun drying)	60	70	80
0	73.0219 ± 1.4787^{e}	73.0219 ± 1.4787^{g}	73.0219 ± 1.4787^{e}	73.0219 ± 1.4787^{d}
1	65.1715 ± 2.1727^{de}	64.6318 ± 3.9778^{f}	62.8999 ± 7.5832^{d}	66.9832 ± 12.8565^{d}
2	56.9004 ± 2.5364^{cde}	57.0372 ± 0.5335^{e}	36.9006 ± 7.7568^{c}	43.2886 ± 1.7682^{c}
3	52.6157 ± 1.4093^{bcd}	46.1436 ± 0.2627^{d}	23.0981 ± 5.6561^{b}	16.6078 ± 2.0619^{b}
4	47.3604 ± 0.3370^{c}	20.1571 ± 1.1543^{c}	11.3559 ± 0.3292^{a}	8.6375 ± 0.2901^{ab}
5	39.1480 ± 2.9841^{b}	8.6099 ± 1.6628^{b}	4.5339 ± 0.7588^{a}	3.0506 ± 0.0298^{a}
6	20.7888 ± 21.6226^{a}	5.6733 ± 0.2861^{ab}	3.3346 ± 0.0376^{a}	2.6401 ± 0.2915^{a}
7	19.8302 ± 1.5133^{a}	5.6088 ± 0.4901^{ab}	3.3470 ± 0.1257^{a}	2.1840 ± 0.1107^{a}
8	19.7302 ± 0.9243^{a}	4.6341 ± 0.2044^{a}	2.9296 ± 0.1622^{a}	2.1562 ± 0.0511^{a}
12	6.5119 ± 1.1684^{a}	-	-	-

Means with different letters in the same column were significantly different at $p < 0.05$

Table 4 Water activity (a_w) of corn cobs dried at different temperatures

Duration (hours)	Temperature (°C)			
	37 ± 3 (sun drying)	60	70	80
0	0.9905 ± 0.0064^{e}	0.9905 ± 0.0064^{f}	0.9905 ± 0.0064^{h}	0.9905 ± 0.0064^{d}
1	0.9860 ± 0.0014^{e}	0.9845 ± 0.0021^{f}	0.9725 ± 0.0021^{g}	0.9730 ± 0.0184^{d}
2	0.9760 ± 0.0028^{e}	0.9470 ± 0.0057^{ef}	0.9265 ± 0.0035^{f}	0.7905 ± 0.0233^{c}
3	0.9635 ± 0.0007^{de}	0.8935 ± 0.0361^{e}	0.9150 ± 0.0071^{e}	0.5025 ± 0.1167^{b}
4	0.9375 ± 0.0092^{cd}	0.7690 ± 0.0396^{d}	0.6415 ± 0.0007^{d}	0.4850 ± 0.0537^{b}
5	0.9360 ± 0.0014^{cd}	0.4500 ± 0.0566^{c}	0.2160 ± 0.0014^{c}	0.1230 ± 0.0042^{a}
6	0.9130 ± 0.0028^{c}	0.2895 ± 0.0021^{b}	0.1880 ± 0.0014^{b}	0.1210 ± 0.0014^{a}
7	0.6725 ± 0.0021^{b}	0.1925 ± 0.0007^{a}	0.1770 ± 0.0099^{b}	0.1025 ± 0.0049^{a}
8	0.6540 ± 0.0156^{b}	0.1745 ± 0.0092^{a}	0.1610 ± 0.0028^{a}	0.0995 ± 0.0219^{a}
12	0.2870 ± 0.0481^{a}	-	-	-

Means with different letters in the same column were significantly different at $p < 0.05$

Table 5 Summary of suitable drying conditions for corn silk and cobs (moisture content <10%)

Drying Condition (°C)	Corn silk			Corn cobs		
	Time (hours)	MC (%)	a_w	Time (hours)	MC (%)	a_w
37 ± 3 (sun drying)	3	6.5065 ± 0.2573	0.2420 ± 0.0170	12	6.5119 ± 1.1684	0.2870 ± 0.0481
60	2	5.6533 ± 0.0245	0.3270 ± 0.0113	5	8.6099 ± 1.6628	0.4500 ± 0.0566
70	1	6.9559 ± 0.0259	0.4600 ± 0.0552	5	4.5339 ± 0.7588	0.2160 ± 0.0014
80	1	6.8472 ± 0.0689	0.4265 ± 0.0191	4	8.6375 ± 0.2901	0.4850 ± 0.0537

The suitable times for each treatment to dry corn silk and cobs to the desired final moisture content of under 10% for use as raw materials for herbal tea are summarized in Table 5. Therefore, corn silk and cob herbal teas were prepared from dried corn silk and cobs obtained from the four different drying conditions in Table 5. The durations for drying corn silk were shorter than for corn cobs because the thinness of the strands of the corn silk allowed air to flow through them. Sun drying took longer than hot air drying; moreover, the moisture content and a_w of the products were higher. This effect was due to the fluctuations of the drying temperature in the sun dryer; furthermore, the velocity and humidity of the drying air depended on the weather, which varied during the day. However, a higher drying temperature provides higher heat energy to remove more moisture from the corn silk and cobs. Likewise, the free water can be removed faster under a higher drying air temperature. Therefore, the drying time, moisture content, and a_w values were much lower when the drying temperature was increased. Singh, Raghuvanshi, and Bhatnagar (2021) have reported that the time for drying corn silk to formulate a herbal tea using a tray drying oven at 40 °C to obtain a moisture content of 7%–9% was 6 hours.

5.2 Physical properties of the corn silk and cob herbal tea

The moisture content and a_w of the corn silk and cob herbal tea samples from different drying conditions are shown in Table 6, and the color of their infusions in L^*, a^*, b^* values are shown in Table 7. The moisture content and a_w of all the tea samples met the criteria found in the TCPS 2562/478 standard. The infusions prepared from these herbal teas had a magenta color, directly related to their anthocyanin content.

Table 6 Moisture content and a_w of the corn silk and cob herbal tea from different drying conditions

Drying conditions (°C)	MC (%)	a_w
37 ± 3 (sun drying)	5.7300 ± 0.6972	0.3081 ± 0.0713
60	7.1809 ± 1.1482	0.3545 ± 0.0221
70	5.7725 ± 0.7407	0.3152 ± 0.0760
80	5.7371 ± 0.4734	0.3081 ± 0.0930

Table 7 Color values of the corn silk and cob infusions from different drying conditions

Drying conditions (°C)	L^*	a^*	b^*
37 ± 3 (sun drying)	20.02 ± 0.05^a	33.36 ± 0.09^c	25.76 ± 0.63^a
60	38.26 ± 0.04^d	33.38 ± 0.03^c	35.92 ± 0.06^d
70	25.53 ± 0.04^b	31.50 ± 0.08^a	30.67 ± 0.33^b
80	29.69 ± 0.06^c	32.91 ± 0.05^b	32.70 ± 0.13^c

Means with different letters in the same column were significantly different at $p < 0.05$

Table 8 Total anthocyanin and total phenolic contents of the corn silk and cob herbal tea prepared under different drying conditions

Drying conditions (°C)	Parameters			
	Total anthocyanin (mg/100g)	Cyanidin (mg/100g)	Peonidin (mg/100g)	Total Phenolic (mg GAE/100g)
37 ± 3 (sun drying)	56.52 ± 1.24^d	23.09 ± 0.89^d	33.43 ± 0.35^d	885.90 ± 7.61^{ns}
60	26.32 ± 0.30^a	6.26 ± 0.34^a	20.06 ± 0.64^a	907.20 ± 53.64^{ns}
70	43.10 ± 2.26^c	14.44 ± 0.78^c	28.66 ± 1.48^c	990.11 ± 39.45^{ns}
80	36.07 ± 0.83^b	10.95 ± 0.10^b	25.12 ± 0.74^b	970.07 ± 39.49^{ns}

Means with different letters in the same column were significantly different at $p < 0.05$

5.3 Chemical properties of the corn silk and cob herbal tea

In this study, the total anthocyanin and total phenolic contents of the corn silk and cob herbal tea obtained from corn silk and cobs dried at different drying conditions were evaluated, as shown in Table 8.

There was no significant difference between the total phenolic contents of the corn silk and cob herbal tea from the various drying conditions. However, the total anthocyanin content of the tea obtained from sun drying was significantly higher than hot air drying at 70, 80, and 60 °C. In addition, the total anthocyanin content of the tea made from ingredients dried at 70 °C was higher than the teas produced at 60 and 80 °C because the magnitude and duration of heating showed a strong influence on the anthocyanin stability. Thus, a high temperature and short treatment time are recommended for maximum anthocyanin retention (Patras et al., 2010). In this study, drying the corn silk at 70 and 80 °C required only 1 hour; for corn cobs, 5 and 4 hours were required, respectively.

Considering the maximum total anthocyanin and total phenolic contents of the tea, as well as the shortest drying time, the best drying condition for corn silk and cobs was 70 °C. Pashazadeh et al. (2020) have reported that the tea made from drying *Rosa pimpinellifolia* fruits with a cabinet dryer at 70 °C exhibited the highest antioxidant properties compared to fruits dried at 50 and 90° C. The total phenolic contents of the corn silk and cob herbal tea from different drying conditions were similar to the 1369 mg GAE / 100 g measured in *Vitex negundo* tea processed by microwave drying, as reported by Rabeta and Vithyia (2013). From the data in Table 8, peonidin content is consistently higher than cyanidin content. Many studies on the identification of anthocyanin in purple corn, including in its waste, have indicated that cyanidin-3-glucoside was the dominant form of anthocyanin, followed by peonidin-3-glucoside and pelargonidin-3-glucoside (Salinas Moreno, Sánchez, Hernández, & Lobato, 2005; Pedreschi & Cisneros-Zevallos, 2007; Ferron et al., 2020; Kapcum et al., 2021). Peniche-Pavia and Tiessen (2020) have reported that cyanidin-based anthocyanins were the most abundant in dark purple-colored kernels, while pelargonidin predominated in the red-pink kernels. Cyanidin and peonidin are anthocyanidins, which give a purplish-red hue (Khoo, Azlan, Tang, & Lim, 2017). Therefore, the main anthocyanidin in “Siam Ruby Corn” may be peonidin: further investigations are required to prove this hypothesis.

5.4 Microbiological content of the corn silk and cob herbal tea

The corn silk and cob herbal teas obtained from different drying conditions were evaluated for microbial qualities, and the data are shown in Table 9.

Table 9 Microbiological qualities of the corn silk and cob herbal teas from different drying conditions

Drying conditions (°C)	Total bacteria (CFU/g)	Yeasts and molds (CFU/g)	*E.coli* (CFU/g)
37 ± 3 (sun drying)	1×10^4	1.67×10^3	15.50
60	6.7×10^2	3.3×10^1	not detected
70	6.7×10^1	not detected	not detected
80	3.3×10^1	not detected	not detected

According to the TCPS 2562/478 standard for dried lotus herbal tea, the total viable count should not exceed 1×10^4 CFU/g, the yeast and mold counts should be below 100 CFU/g, and *E. coli* should be absent from 100 ml of sample. The corn silk and cob herbal tea obtained from dried raw materials at 70 and 80 °C met the criteria specified in the standard.

6. Conclusion

Based on the results of this study, the best drying condition for the production of dried corn silk and cobs to be used to make corn silk and cob herbal tea was a hot air dryer at 70 °C for 1 hour for corn silk and 5 hours for corn cobs. The characteristics of the tea were 43.10 mg total anthocyanin per 100 g and 990.11 mg total phenolic compounds (as GAE) per 100 g. Since the drying technique affects phytochemicals and the qualities of the silk and cobs of red sweet corn, different drying techniques or combinations thereof should be investigated to improve the sustainable processing of the herbal tea.

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