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RESEARCH COMMUNICATION

Influence of thermal treatment on Anthocyanin, total phenolic content and antioxidant capacity of Pigmented Maize (*Zea mays* L.)

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ABSTRACT

Pigmented maize (*Zea mays* L.) is a healthy crop due to its perfect proximates and phytochemicals. Thermal treatment was widely used to enhance phytochemical constituents in different kinds of crops. This research evaluated the impact of temperature (100, 115, 130 °C) and duration (10, 15, 20 min) in roasting to anthocyanin, total phenolic content and antioxidant capacity of pigmented maize. Results showed that thermal treatment at 115 °C in 10 min significantly improved anthocyanin in pigmented maize; however, this content would be lower at higher temperatures or prolonged exposing time. Meanwhile, total phenolic content and antioxidant capacity in the pigmented maize were recorded at the highest level when being roasted at 100 °C for 10 min. This research proved that phytochemical constituents and antioxidant capacity inside the pigmented maize would be seriously damaged at high temperatures and extended duration in roasting. By this, producers should pay more attention to thermal conditions in roasting.

Introduction

Pigmented maize (*Zea mays* L.) is an important crop in Vietnam. It contains high carbohydrates, proteins, lipids, anthocyanins, minerals and phenolics (1). Abundant anthocyanins and phenolics are located in the aleurone and pericarp monolayer of the cereal contributing to the pigment of the maize species (2). Pigmented maize seed has a high content of anthocyanin in the aleurone layer and lowered in the starchy endosperm (3). Anthocyanins and phenolics play functional properties against chronic diseases due to their antioxidant and anti-inflammatory activity (4, 5). They offer protection against mutagenesis (6). Maize is commonly utilized for animal feed, cornmeal, grits, starch, flour, tortillas and snacks (5). Pigmented maize is roasted to turn into bread in the bakery industry.

Roasting involves applying dry heat to change the physicochemical, nutritional and phytochemical properties of raw material (7). It is one kind of thermal treatment widely applied in grain processing to improve nutritional bioavailability, phytochemical efficiency, organoleptic property and deduct the toxic components (8). The roasting of maize grains improved aroma, antioxidant capacity, food quality of semi and final products (9). Phytic acid in oat flour was greatly minimized by roasting to support calcium bioavailability (10). The mineral bioavailability in millet and biofortified bean flour was also significantly improved by roasting treatment (11, 12). Roasting induced modification in the proximate composition and biological properties of the coffee bean, supporting the release of derivative antioxidants (13). Roasted rice wine had a better flavour compared to unroasted rice wine (8). Rice powder had decreased levels of free amino acids by roasting at high temperatures and extended duration (14). Roasting had a positive impact on bioactive constituents in soybean (15), wheat (16), barley (17), pistachio nuts (18), cocoa beans (19), coffee beans (20) and wattle seeds (21). The objective of this study was to verify the influence of temperature (100, 115, 130 °C) and time (10, 15, 20 min) in convective roasting to anthocyanin, total phenolic content and antioxidant capacity of pigmented maize.

Materials and Methods

Material

The pigmented maize was collected from Mỹ Xuyên district, Soc Trang province, Vietnam. It was harvested at maturity and dehydrated in an infrared drying oven to 15% moisture content. Chemical reagents were all analytical grade supplied from Merck (Germany) and Sigma Aldrich (USA).

Researching method

500 gm of each pigment maize seed sample was roasted at temperature (100, 115, 130 °C) and duration (10, 15, 20 min) in the oven (Memmert, model Universal oven UF30). The chamber load was exposed to defined temperatures at atmospheric pressure in the interior of a drying oven. Thermal energy was transferred to the chamber load by convection and radiation. The roasted seed was then cooled to an ambient condition, ready for analysis. Anthocyanin content (mg/100 gm) was measured following Abdel-Aal and Hucl (22). Total phenolic content (TPC, mg GAE/100 gm) was examined by Folin-Ciocalteu reagent assay (23). Free radical scavenging activity (DPPH, mg Trolox/100 gm) was evaluated by the method described by Bakar (24).

Statistical analysis

The experiments were run in 5 replications with different groups of samples. The data were presented as mean±standard deviation. Statistical analysis was performed by the Statgraphics Centurion version XVI.

Results and Discussion

Anthocyanin exerted a major activity against oxidative stress (6). The impact of roasting temperature and duration on anthocyanin content in the roasted pigmented maize was shown in Table 1. It was realized that the highest anthocyanin content (31.15±0.02 mg/100 gm) in the pigmented maize was noticed by roasting at 115 °C for 10 min. This content would be lower at higher temperatures or prolonged exposing time. Anthocyanin was highly sensitive to high temperatures (25). Anthocyanin was seriously damaged at higher roasting temperature (> 115 °C) and longer drying times (> 10 min) due to the decomposition of anthocyanin molecules through the hydrolysis of glycosidic links (26). The temperature could seriously affect anthocyanin's stability and its pigment intensity (27). Anthocyanin in black rice grain decreased dramatically with an increase in temperature from 100–140 °C (28). Anthocyanin in glutinous rice powder was seriously decomposed by spray-drying at 160–180 °C (29). One study reported the decomposition of anthocyanin in potatoes treated at a temperature >100 °C (30). In a similar research, anthocyanin decomposed after the rupture of glycosidic moiety and the establishment of other chalcones (31). The most suitable roasting temperature and duration for achieving the highest yield of anthocyanin was 100 °C up to 20 min for pigmented rice and 200 °C for 20 min for non-pigmented rice (32).

Table 1. Anthocyanin content (mg/100 gm) in the pigmented maize affected by roasting time (min) and temperature (°C)

Roasting time (min)	Roasting temperature (°C)	Anthocyanin content (mg/100 gm)
10	100	29.83±0.00[b]
	115	31.15±0.02[a]
	130	30.59±0.01[ab]
15	100	26.76±0.03[c]
	115	29.37±0.02[b]
	130	27.93±0.00[bc]
20	100	24.50±0.04[d]
	115	27.64±0.01[bc]
	130	26.31±0.03[c]

Note: the numbers were presented as the mean of 3 samples; the same symbol was considered insignificant difference (α = 5%).

Major phenolics from maize were ferulic acid and anthocyanin (5). The efficiency of roasting temperature and time on total phenolic content in the roasted pigmented maize was presented in Table 2. It is noticed that the highest total phenolic content (169.52±0.03 mg GAE/100 gm) in the pigmented maize was noticed by roasting at 100 °C for 10 min. Longer exposure time and higher temperature resulted in low phenolic content. It is suggested that the roasting process significantly decreased total phenolic content. Roasting induced an accumulation of total phenolic content due to thermal modification in chemical constituents via cell wall disruption in quinoa seed (33). Degradation in insoluble phenolics and an accumulation of soluble ones were noticed in peanut seeds under roasting at 170 °C (31). The total phenolics in black soybean were greatly degraded by roasting at 210 °C for 30 min (34). Phenolics would be accelerated by roasting from 30–90 min at 150 °C, however, it was significantly decomposed by roasting at an extended period (35). Roasting was considered one of the most innovative processing techniques to improve total phenolics in broomcorn millet (36). Phenolic content in pistachio was accelerated under roasting at 110 °C for 16 min (37). Total phenolic content in fenugreek seed was greatly improved by roasting at 130 °C for 7 min (38). In another research, the total polyphenol content in roasted maize dramatically increased with higher roasting temperature and longer roasting time (39).

Table 2. Total phenolic content (mg GAE/100 gm) in the pigmented maize affected by roasting time (min) and temperature (°C)

Roasting time (min)	Roasting temperature (°C)	Total phenolic content (mg GAE/100 gm)
10	100	169.52±0.03[a]
10	115	152.17±0.01[b]
10	130	125.32±0.00[c]
15	100	158.41±0.02[ab]
15	115	141.30±0.04[bc]
15	130	113.68±0.01[cd]
20	100	102.14±0.03[d]
20	115	86.14±0.00[de]
20	130	73.19±0.02[e]

Note: the numbers were presented as the mean of 3 samples; the same symbol was considered insignificant difference (α = 5%).

The durable DPPH radical with maximum absorption at 515 nm is commonly applied to estimate the free radical scavenging activity of hydrogen-donating antioxidants in cereal (40). The efficiency of roasting temperature and time on DPPH antioxidant capacity in the roasted pigmented maize is presented in Table 3. It is noticed that the highest DPPH antioxidant capacity (89.15±0.02 mg Trolox/100 gm) in the pigmented maize was recorded by roasting at 100 °C for 10 min. Longer exposure time and higher temperature induce low antioxidant capacity.

Table 3. DPPH antioxidant capacity (mg Trolox/100 gm) in the pigmented maize affected by roasting time (min) and temperature (°C)

Roasting time (min)	Roasting temperature (°C)	DPPH (mg Trolox/ 100 gm)
10	100	89.15±0.02[a]
10	115	83.42±0.03[b]
10	130	78.34±0.01[c]
15	100	85.76±0.00[ab]
15	115	81.09±0.02[bc]
15	130	75.21±0.03[cd]
20	100	72.16±0.01[d]
20	115	69.83±0.02[de]
20	130	63.72±0.03[e]

Note: the numbers were presented as the mean of 3 samples; the same symbol was considered insignificant difference (α = 5%).

Antioxidants in pigmented maize might mostly be covalently bonded with insoluble polymers (41). Mild heating induced cell wall disruption and release of antioxidants from insoluble particles of maize. The difference in antioxidant capacity could originate from the formation of derivative elements with potential antioxidant capacity and decomposition under excess temperature and duration (42, 43). Heated samples showed chain-breaking and oxygen-scavenging activities (44). Roasting was reported to enhance antioxidant potential by alteration of biochemical ingredients of cereal grains (33). Antioxidant activity in fenugreek seed was greatly improved by roasting at 130 °C for 7 min (38). Antioxidant capacity in the unpolished grain of non-pigmented rice was increased by roasting at 60 °C for 3 min (45). The most suitable roasting temperature and duration for achieving the highest total phenol content and antioxidant capacity was 100 °C in 20 min for pigmented rice and 200 °C for 20 min for non-pigmented rice (31).

Conclusion

Pigmented maize included a significant amount of nutrients, minerals, vitamins and specific flavours. The anthocyanin, total phenolic and antioxidant capacity in pigmented maize were unstable and susceptible to degradation by high temperature. They would be maintained effectively by roasting at temperature 100°-115 °C within 10 min. Bioactive constituents in the pigmented maize would be significantly damaged by excess thermal treatment. Therefore, cereal processors should concentrate on thermal conditions to minimize the harmful impacts on phytochemical components. Roasting could be considered an important pretreatment step to prolong the food stability and enhance the efficiency of further processing steps.

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Conflict of interests

The author strongly confirms that this research was conducted with no conflict of interest.

References

1. Pedreschi R, Cisneros-Zevallos L. Phenolic profiles of Andean purple corn (*Zea mays* L.). Food Chemistry. 2007;100:956-63. https://doi.org/10.1016/j.foodchem.2005.11.004
2. Espinosa-Trujillo E, Mendoza-Castillo M, Castillo-Gonzalez F, Ortiz-Cereceres J, Delgado-Alvarado A, Carrillo-Salazar A. Anthocyanin accumulation in pericarp and aleurone layer of maize kernel and their genetic effects on native pigmented varieties. Revista Fitotecnia Mexicana. 2009;32:303-09.
3. Betran FJ, Bockholt AJ, Rooney LW. Blue corn. In AR Hallauer (Ed.), Specialty Corns, 2nd ed, CRC Press, Boca Raton, Florida, USA, 2000;pp. 305-14.
4. Urias-Peraldi M, Gutierrez-Uribe JA, Preciado-Ortiz RE, Cruz-Morales AS, Serna-Saldivar SO, Garcia-Lara S. Nutraceutical profiles of improved blue maize (*Zea mays*) hybrids for subtropical regions. Field Crops Research. 2013;141:69-76. https://doi.org/10.1016/j.fcr.2012.11.008
5. Tajamul RS, Kamlesh P, Pradyuman K, Fatih Y. Maize—A potential source of human nutrition and health:A review. Cogent Food and Agriculture. 2016;2, 1. https://doi.org/10.1080/23311932.2016.1166995
6. Magana-Cerino JM, Peniche-Pavia HA, Tiessen A, Gurrola-Diaz CM. Pigmented maize (*Zea mays* L.) contains anthocyanins with potential therapeutic action against oxidative stress – a review. Pol J Food Nutr Sci. 2020;70:85-99. https://doi.org/10.31883/pjfns/113272
7. Oliviero T, Capuano E, CäMmerer B, Fogliano V. Influence of roasting on the antioxidant activity and HMF formation of a cocoa bean model systems. Journal of Agriculture and Food Chemistry. 2008;57:147-52. https://doi.org/10.1021/jf802250j
8. Chen J, Yan X. Analyzing the characteristics of roasting process for Chinese rice wine by fluidized bed using superheated steam. Food Science and Technology Research. 2016;22:159-72. https://doi.org/10.3136/fstr.22.159
9. Chung HS, Chung SK, Youn KS. Effects of roasting temperature and time on bulk density, soluble solids, browning index and phenolic compounds of corn kernels. Journal of Food Processing and Preservation. 2011;35:832-39. https://doi.org/10.1111/j.1745-4549.2011.00536.x
10. Tiwari N and Awasthi P. Effect of different processing techniques on nutritional characteristics of oat (*Avena sativa*) grains and formulated weaning mixes. Journal of Food Science and Technology. 2014;51:2256-59. https://doi.org/10.1007/s13197-012-0694-z
11. Nkundabombi MG, Nakimbugwe D, Muyonga JH. Effect of processing methods on nutritional, sensory and physicochemical characteristics of biofortified bean flour. Food Science and Nutrition. 2015;4:384-97. https://doi.org/10.1002/fsn3.301
12. Singh N, David J, Thompkinson DK, Seelam BS, Rajput H, Morya S. Effect of roasting on functional and phytochemical constituents of finger millet (*Eleusine coracana* L.). The Pharma Innovation Journal. 2018;7:414-18. https://www.thepharmajournal.com/archives/2018/vol7issue4/PartG/7-3-90-468.pdf
13. Wang HY, Qian H, Yao WR. Melanoidins produced by the Maillard reaction:Structure and biological activity:A review. Food Chemistry. 2011;128:573–84. https://doi.org/10.1016/j.foodchem.2011.03.075
14. Lee GC, Kim SJ, Koh BK. Effect of roasting condition on the physicochemical properties of rice flour and the quality characteristics of tarakjuk. Korean Journal of Food Science and Technology. 2003;35:905-13.
15. Lee SW, Lee JH. Effects of oven-drying, roasting, and explosive puffing process on isoflavone distributions in soybeans. Food Chemistry. 2009;112:316–20. https://doi.org/10.1016/j.foodchem.2008.05.065
16. Kring U, El-Saharty YS, El-Zeany BA, Pabel B, Berger RG. Antioxidant activity of extracts from roasted wheat germ. Food Chemistry. 2000;71:91–95. https://doi.org/10.1016/S0308-8146(00)00148-5
17. Sharma P, Gujral HS. Effect of sand roasting and microwave cooking on antioxidant activity of barley. Food Research International. 2011;44:235–40. https://doi.org/10.1016/j.foodres.2010.10.030

18. Yazdanpanah H, Mohammadi T, Abouhossain G, Cheraghali AM. Effect of roasting on degradation of aflatoxins in contaminated pistachio nuts. Food Chemistry Toxicology. 2005;43:1135–39. https://doi.org/10.1016/j.fct.2005.03.004
19. Redgwell RJ, Trovato V, Curti D. Cocoa bean carbohydrates:roasting induced changes and polymer interactions. Food Chemistry. 2003;80:511–16. https://doi.org/10.1016/S0308-8146(02)00320-5
20. Vignoli JA, Viegas MC, Bassoli DG, Benassi MT. Roasting process affects differently the bioactive compounds and the antioxidant activity of arabica and robusta coffees. Food Research International. 2013;61:279–85. https://doi.org/10.1016/j.foodres.2013.06.006
21. Ee KY, Agboola S, Rehman A, Zhao J. Characterisation of phenolic components present in raw and roasted wattle (*Acacia victoriae* Bentham) seeds. Food Chemistry 2011;129:816–21. https://doi.org/10.1016/j.foodchem.2011.05.028
22. Abdel-Aal ESM and Hucl P. A rapid method for quantifying total anthocyanins in blue aleurone and purple pericarp wheats. Cereal Chemistry Journal. 1999;76:350-54. https://doi.org/10.1094/CCHEM.1999.76.3.350
23. Cristina CM, Oana C, Lucia D, Monica H. Morphological characteristics, phenolic and terpenoid profiles in garden *Chrysanthemum* grown in different nutritional conditions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 2015;43:371-79. https://doi.org/10.15835/nbha43210060
24. Bakar MFA, Sanusi SB, Bakar FIA, Cong OJ, Mian Z. Physicochemical and antioxidant potential of raw unprocessed honey from Malaysian stingless bees. Pakistan Journal of Nutrition 2017;16:888-94. https://doi.org/10.3923/pjn.2017.888.894
25. Patras A, Brunton NP, O' Donnell C, Tiwari BK. Effect of thermal processing on anthocyanin stability in foods;mechanisms and kinetics of degradation. Trends in Food Science and Technology. 2010;21:3-11. https://doi.org/10.1016/j.tifs.2009.07.004
26. Sadilova E, Carle R, Stintzing FC. Thermal degradation of anthocyanins and its impact on color and in vitro antioxidant capacity. Molecular Nutrition and Food Research. 2007;51:1461-71. https://doi.org/10.1002/mnfr.200700179
27. Cevallos-Casals BA, Cisneros-Zevallos L. Stability of anthocyanin-based aqueous extracts of Andean purple corn and red-fleshed sweet potato compared to synthetic and natural colorants. Food Chemistry. 2004;86:69–77. https://doi.org/10.1016/j.foodchem.2003.08.011
28. Tanghiranrat J, Anprung P. Effect of dry heating temperature and time on radical scavenging activities and bioactive compounds in black rice varieties (*Oryza sativa* L. *indica*). Journal of Food Science and Agricultural Technology 2015;1:73-78.
29. Kanha N, Laokuldilok T. Effects of spray-drying temperatures on powder properties and antioxidant activities of encapsulated anthocyanins from black glutinous rice bran. Chiang Mai University Journal of Natural Sciences. 2014;13:411-23. https://doi.org/10.12982/CMUJNS.2014.0045
30. Nayak B, Berrios JDJ, Powers JR, Tang J. Effect of extrusion on the antioxidant capacity and color attributes of expanded extrudates prepared from purple potato and yellow pea flour mixes. Journal of Food Science. 2011;76:874–83. https://doi.org/10.1111/j.1750-3841.2011.02279.x
31. Ferreira CD, Ziegler V, Bubolz VK, Da Silva J, Cardozo MMC, Elias MC, De Oliveira M. Effects of the roasting process over the content of secondary metabolites from peanut grains (*Arachis hypogaea* L.) with different colorations of Testa. Journal of Food Quality. 2016;39:685-94. https://doi.org/10.1111/jfq.12235
32. Yamuangmorn S, Sreethong T, Saenchai C, Rerkasem B, Promuthai C. Effects of roasting conditions on anthocyanin, total phenolic content and antioxidant capacity in pigmented and non-pigmented rice varieties. International Food Research Journal. 2021;28:73–82. http://www.ifrj.upm.edu.my/28%20(01)%202021/DONE%20-%2007%20-%20IFRJ19842.R3.pdf
33. Carciochi RA, D'Alessandro LG, Manrique GD. Effect of roasting conditions on the antioxidant compounds of quinoa seeds. International Journal of Food Science and Technology. 2016;51:1018-25. https://doi.org/10.1111/ijfs.13061
34. Zhou R, Cai W, Xu B. Phytochemical profiles of black and yellow soybeans as affected by roasting. International Journal of Food Properties. 2017;20:3179-90. https://doi.org/10.1080/10942912.2017.1280678
35. Rizki H, Kzaiber F, Elharfi M, Ennahli S, Hanine H. Effects of roasting temperature and time on the physicochemical properties of sesame (*Sesamum indicum* L.) seeds. International Journal of Innovation and Applied Studies. 2015;11:148-55.
36. Kalam Azad MO, Jeong DI, Adnan M, Salitxay T, Heo JW, Naznin MT, Park CH. Effect of different processing methods on the accumulation of the phenolic compounds and antioxidant profile of broomcorn millet (*Panicum miliaceum* L.) flour. Foods 2019;8:203. https://doi.org/10.3390/foods8070230
37. Ghazzawi HA, Al-Ismail K. A comprehensive study on the effect of roasting and frying on fatty acids profiles and antioxidant capacity of almonds, pine, cashew and pistachio. Journal of Food Quality. 2017:9038257. https://doi.org/10.1155/2017/9038257
38. Pandey H, Awasthi P. Effect of processing techniques on nutritional composition and antioxidant activity of fenugreek (*Trigonella foenum-graecum*) seed flour. Journal of Food Science and Technology 2015;52:1054-60. https://doi.org/10.1007/s13197-013-1057-0
39. Koan SW, Mi JK, Hyun-Joo K, Ji HL, Byong WL, Gun-Ho J, Byoung KL, Sun LK. Changes in the functional components and radical scavenging activity of maize under various roasting conditions. Food Science Biotechnology. 2018;27:837–45. https://doi.org/10.1007/s10068-017-0294-9
40. Lee K, Ham H, Kim MJ, Ko JY, Kim HJ, Oh SK, Jeong HS, Woo KS. Effects of heating condition and cultivar on phenolic compounds and their radical scavenging activity on sorghum. Academic Journal of Biotechnology. 2016;4:347–52.
41. Peleg H, Naim M, Rouseff RL, Zehavi U. Distribution of bound and free polyphenolic acids in oranges (*Citrus sinensis*) and grapefruit (*Citrus paradisi*). Journal of Science Food and Agriculture. 1991;57:417–26. https://doi.org/10.1002/jsfa.2740570312
42. Jeong SM, Kim SY, Kim DR, Nam KC, Ahn DU, Lee SC. Effect of seed roasting conditions on the antioxidant activity of defatted sesame meal extracts. Journal of Food Science. 2004; 69:377-81. https://doi.org/10.1111/j.1365-2621.2004.tb10701.x
43. Jannat B, Oveisi MR, Sadeghi N, Hajimahmoodi M, Behzad M, Nahavandi B, Oveisi M. Effect of roasting process on total phenolic compounds and γ-tocopherol contents of Iranian sesame seeds (*Sesamum indicum*). Iranian Journal of Pharmaceutical Research. 2013;12:751-58.
44. Jung HA, Lee HJ, Kim YA, Park KE, Ahn JW, Lee BJ, Moon SG, Seo Y. Antioxidant activity of *Artemisia capillaris* Thunberg. Food Science Biotechnology. 2004;13:328–31.
45. Ruen-ngam D, Thawai C, Sukonthamut S, Nokkoul R, Tadtong S. Evaluation of nutrient content and antioxidant, neuritogenic and neuroprotective activities of upland rice bran oil. Science Asia. 2018;44:257-67. https://doi.org/10.2306/scienceasia1513-1874.2018.44.257

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