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PRODUCTION OF DIETARY FIBER POWDER HAVING
ANTIOXIDANTS, GLUCOSINOLATES AND SULFORAPHANE
FROM WHITE CABBAGE OUTER LEAVES

MISS YARDFON TANONGKANKIT

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF
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Abstract

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White cabbage (*Brassica oleracea* L. var. capitata) is an important source of dietary fiber (DF) and various phytochemicals, which are claimed to possess antioxidant and anticarcinogenic activities. It has been reported that outer leaves of white cabbage, a typical by-product from a cabbage processing plant, has potential of being transformed into DF powder. However, the effects of various processing steps on the antioxidants and anticarcinogenic substances of DF powder had not yet been systematically investigated.

This work aimed at studying the effects of various processing steps, i.e., sample preparation, which included sample slicing and blanching using either hot water or steam, as well as drying methods viz. hot air drying and vacuum drying, on the evolutions of various phytochemicals in cabbage outer leaves. The phytochemicals of interest were phenolics (measured in terms of the total phenolics content, TPC), vitamin C, β -carotene, α -tocopherol as well as glucosinolates and sulforaphane, which possess anticarcinogenic properties. Overall, the results showed that preparation steps did not lead to any significant changes in the compositions of the DF powder. On the other hand, steam blanching was noted to better preserve antioxidants and glucosinolates than water blanching. Vacuum drying led to better retention of antioxidants and glucosinolates as well as color than hot air drying. The results suggested that cabbage outer leaves should be prepared into DF powder by steam blanching prior to slicing in combination with vacuum drying at 80 °C.

In terms of sulforaphane, however, it was found that steam blanching was not a suitable pretreatment as this compound is rather heat sensitive and heat during blanching could destroy myrosinase, endogenous enzyme responsible for the formation of sulforaphane in cabbage. A recommended preparation was chopping cabbage outer leaves into a size of 1.7-2.5 mm and incubating at 25 °C for 30 min prior to drying. The results further showed that the formation of sulforaphane occurred when the cabbage temperature during drying was in the range of 25-53.5 °C and thermal degradation took place once the cabbage temperature exceeded this range. A semi-empirical heat transfer and kinetic model was proposed to predict the evolution of sulforaphane during drying. Hot air drying the chopped raw cabbage leaves at 60 °C was suggested as an optimum condition to obtain the highest retention of sulforaphane in cabbage DF powder.

In addition to transforming the cabbage outer leaves into DF powder associated with high contents of phytochemicals, the feasibility of using microwave-assisted extraction (MAE) of sulforaphane was investigated. The results showed that MAE was more effective than conventional extraction as the former exhibited higher yield of sulforaphane in a much shorter extraction time. Higher microwave power resulted in a shorter extraction time. There was no difference for the highest extraction yield obtained from the fresh and semi-dried samples. The results also showed that the use of different solvents did not have any significant effect on the MAE of either fresh or semi-dried sample. By considering the whole process, MAE of sulforaphane from fresh cabbages using water as the solvent at 390 W is suggested.

Keywords: Antioxidants / Blanching / Cabbage / Drying / Glucosinolates / Microwave extraction / Sulforaphane

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บทคัดย่อ

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กะหล่ำปลี (*Brassica oleracea* L. var. capitata) เป็นแหล่งสำคัญของใยอาหารและสารพฤกษเคมีที่มีฤทธิ์ต้านอนุมูลอิสระและฤทธิ์ต้านมะเร็ง โดยมีรายงานว่ากาบไบนอกของกะหล่ำปลี ซึ่งเป็นเศษเหลือทิ้งจากโรงงานแปรรูป มีศักยภาพในการที่จะนำมาเปลี่ยนเป็นใยอาหารผง อย่างไรก็ตามยังไม่มีการศึกษาผลของขั้นตอนกระบวนการผลิตที่มีต่อการเปลี่ยนแปลงสารต้านอนุมูลอิสระและสารต้านมะเร็งในใยอาหารผงจากกาบไบนอกของกะหล่ำปลี

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาผลของขั้นตอนการผลิต ได้แก่ การเตรียมตัวอย่าง ซึ่งรวมไปถึง การหั่นและการลวก โดยใช้น้ำร้อนหรือน้ำ และวิธีการอบแห้งด้วยลมร้อนหรือสุญญากาศ ที่มีต่อการเปลี่ยนแปลงสารพฤกษเคมีในกาบไบนอกของกะหล่ำปลี โดยสารพฤกษเคมีที่สนใจในงานวิจัยนี้ ได้แก่ สารฟีนอลิก (โดยวิเคราะห์ในรูปของสารประกอบฟีนอลิกทั้งหมด) วิตามินซี เบต้าแคโรทีน แอลฟาโทโคฟีรอล และสารกลุ่มกลูโคซิโนเลต ซึ่งรวมไปถึงซัลโฟราเฟน ซึ่งมีฤทธิ์ต้านมะเร็ง ผลการศึกษาแสดงว่า ขั้นตอนการเตรียมตัวอย่างไม่มีผลต่อองค์ประกอบของใยอาหารผง อย่างไรก็ตามการลวกกะหล่ำปลีด้วยไอน้ำสามารถรักษาสารต้านอนุมูลอิสระและสารกลุ่มกลูโคซิโนเลตไว้ได้ดีกว่าการลวกด้วยน้ำร้อน ใยอาหารผงที่ผ่านการอบแห้งแบบสุญญากาศมีสารต้านอนุมูลอิสระและสารกลุ่มกลูโคซิโนเลต และดีกว่าใยอาหารผงที่ผ่านการอบแห้งด้วยลมร้อน จากผลจากการศึกษาสรุปได้ว่า

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สภาวะที่เหมาะสมในการผลิตโยอาหารผงจากกาบไบนอกของกะหล่ำปลี คือการลวกด้วยไอน้ำก่อนการหันร่วมกับการอบแห้งแบบสุญญากาศที่อุณหภูมิ 80 องศาเซลเซียส

อย่างไรก็ตาม ในการศึกษาการเปลี่ยนแปลงปริมาณสารซัลโฟราเฟน พบว่า การเตรียมตัวอย่างโดยการลวกด้วยไอน้ำไม่เหมาะสม เนื่องจากสารนี้ไม่ทนต่อความร้อนและความร้อนสามารถทำลายโมโรซิเนส ซึ่งเป็นเอนไซม์ที่ใช้ในการเปลี่ยนสารกลูโคซิโนเลตเป็นซัลโฟราเฟน การเตรียมตัวอย่างที่แนะนำคือ การบดกะหล่ำปลีให้มีขนาดอนุภาค 1.70 ถึง 2.45 มิลลิเมตร และบ่มที่อุณหภูมิ 25 องศาเซลเซียส เป็นเวลา 30 นาที ก่อนการอบแห้ง นอกจากนี้ยังพบว่า การสร้างซัลโฟราเฟนจะเกิดขึ้นเมื่ออุณหภูมิของกะหล่ำปลีในระหว่างการอบแห้งอยู่ในช่วง 25 ถึง 53.5 องศาเซลเซียส และการสลายตัวของซัลโฟราเฟนจะเกิดขึ้นเมื่ออุณหภูมิกะหล่ำปลีสูงกว่าอุณหภูมิในช่วงดังกล่าว ทั้งนี้ได้สร้างสมการการถ่ายเทความร้อนและจลนพลศาสตร์ทางเคมีเพื่อทำนายการเปลี่ยนแปลงปริมาณสารซัลโฟราเฟนในระหว่างการอบแห้ง การทดลองในส่วนนี้สามารถสรุปได้ว่า สภาวะที่เหมาะสมในการอบแห้งกาบไบนอกของกะหล่ำปลีเพื่อให้ได้ปริมาณสารซัลโฟราเฟนสูงสุดในโยอาหารผงคือ การอบแห้งด้วยลมร้อนที่อุณหภูมิ 60 องศาเซลเซียส

ในส่วนสุดท้ายเป็นการศึกษาความเป็นไปได้ในการใช้ไมโครเวฟเพื่อช่วยในการสกัดซัลโฟราเฟนจากกาบไบนอกของกะหล่ำปลี ผลการศึกษาพบว่าไมโครเวฟสามารถเพิ่มประสิทธิภาพการสกัดซัลโฟราเฟน โดยใช้เวลาการสกัดสั้นกว่าการสกัดด้วยวิธีสกัดที่ใช้โดยทั่วไป การเพิ่มกำลังไมโครเวฟส่งผลให้เวลาที่ใช้ในการสกัดลดลง และไม่พบความแตกต่างของปริมาณซัลโฟราเฟนสูงสุดที่สกัดได้จากทั้งกะหล่ำปลีสดหรือกะหล่ำปลีกึ่งแห้ง นอกจากนี้ยังพบว่าการใช้สารสกัดที่แตกต่างกันไม่ส่งผลต่อการสกัดด้วยไมโครเวฟ ทั้งในกรณีกะหล่ำปลีสดหรือกะหล่ำปลีกึ่งแห้งอย่างมีนัยสำคัญ หากพิจารณาทั้งกระบวนการ อาจสรุปได้ว่า สภาวะที่เหมาะสมที่สุดในการสกัดซัลโฟราเฟนคือ การใช้ไมโครเวฟสกัดสารจากกะหล่ำปลีสด โดยใช้น้ำเป็นสารสกัดที่กำลังไมโครเวฟ 390 วัตต์

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