DEVELOPMENT OF CONCENTRATED SPINACH PRODUCT WITH VACUUM EVAPORATOR

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GENERAL INFORMATION

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KEYWORD

Brix;
Spinach;
Vacuum concentration;
Viscosity.

ABSTRACT

The objective of this study was to investigate the production of spinach concentrate. The research has shown that several factors affect the concentration process, including the ratio of vegetables to water in the grinding process, the content of potatoes mixed into the product, and the time of concentration. After experimentation, the optimal parameters were found to be a vegetable-to-water ratio of 150:50, a potato content of 50g, and an concentration time of 20 minutes. The resulting vegetable concentrate had a viscosity of 6283 mPa.s, moisture content of 81.04 ± 0.07 and Brix value of 7.0 ± 0.3 with omega-3 content including *α-linolenic acid* (ALA), *Eicosatrienoic* (EPA), *Docosahexaenoic acid* (DHA) in the final product is 51.4 ± 0.3 mg/100g.

1. INTRODUCTION

Spinach (*Spinacia oleracea L.*) is indeed one of the most nutritious leafy vegetables, member of the *Amaranthaceae* family (Roberts & Moreau, 2016). It is true that spinach contains various phytochemicals with different biological activities that are associated with its anti-obesity, anti-cancer, hypolipidemic, and hypoglycemic characteristics (Roberts & Moreau, 2016). It is packed with protein, carbohydrates, and fat, in addition to a wealth of minerals and vitamins that offer exceptional nutritional value.

Spinach is known to be a rich source of micronutrients such as iron, calcium, magnesium, copper, vitamins, and antioxidants, according to some studies (Roughani, A., 2019). It also contains small amounts of vitamins E, A, C, K, folate, thiamine (B1), pyridoxine (B6), riboflavin (B2), and omega 3, which play an essential role in the maintenance, repair, and regulation of human tissues. Furthermore, spinach is a rich source of dietary fiber (Slavin, and Lloyd, 2012), with just 100 grams of spinach, you can get two-thirds of your daily requirement of vitamin A, almost all the folic acid you need in a day, half the dose of vitamin C, almost a quarter of your daily iron needs, and over a quarter of your daily magnesium needs (M.A. Nur, 2023).

It has been found that alternative technology is required to expedite moisture removal in vegetable or fruit extracts such as orange to better preserve their beneficial attributes. A recent study evaluated the vacuum concentration (VC) process for rapid evaporation of moisture from the extracts.

During VC, moisture is evaporated through heating of the extract at a lower boiling point of water under vacuum. The process involves passing an electric current through the food from electrodes at both ends of the equipment, and the electrical energy is converted to heat depending on the internal energy generated. Additionally, because VC is performed under a vacuum, the heat loss of the internal energy generation is minimized. A study by Vikram, Ramesh, and Prapulla (2005) found that the highest vitamin C retention after several thermal processes. The authors explained that a shorter lag time of this method resulted in lesser degradation of vitamin C. Recently, Negri Rodríguez et al. (2021) reported that there was a greater color preference and a higher level of sensory attributes of VC-treated concentrates than those of concentrates treated using conventional heating.

From that, we have conducted extensive research on developing a product that meets the needs of today's busy life - vacuum concentrated spinach. Through our research, we have optimized the parameters to ensure that we utilize and retain the most valuable nutritional components in vegetables through VC method. We strongly believe that this product is not only necessary but also has scientific significance, economic practicality, and profound social value. We are confident that this product will make a positive impact on people's lives and help them achieve a healthy and balanced diet.

2. MATERIALS AND METHODS

2.1. Materials

Spinach and potatoes were purchased from Trang Dai market, Bien Hoa city, Dong Nai province.

2.2. Research method

During Experiments 1, 2, and 3, the concentration process was studied with respect to several factors, including the ratio of vegetables to water during the milling process, the amount of potatoes used in the product, and the duration of concentration. The moisture, Brix, and viscosity levels were monitored throughout the experiments.

In order to investigate the impact of the ratio of vegetables to water during the grinding process, we conducted an experiment with five different ratios: A1 (120:80), A2 (130-70), A3 (140-60), A4 (150-50), A5 (160-40), and A6 (170-30). The experiment was designed with one factor, five levels, and three replications for each treatment.

Experiment 2 was conducted to study the effect of the content of potatoes mixed into the product. The experiment included three levels of potatoes: B1 (40g), B2 (50g), and B3 (60g). The experiment was arranged in a completely randomized design, with three levels of potatoes and three replications.

Experiment 3 was carried out to examine the impact of concentration time on dry matter content using a vacuum concentrator, with four different durations tested: 10 minutes, 20 minutes, 30 minutes, 40 minutes, 50 minutes. The concentration process was conducted at a temperature of 70°C with 0.4 Bar. The goal of this experiment was to identify the optimal parameters for the concentration process.

After the concentration process, the final product was analyzed to determine the effectiveness of the vacuum concentration method in retaining omega-3 content.

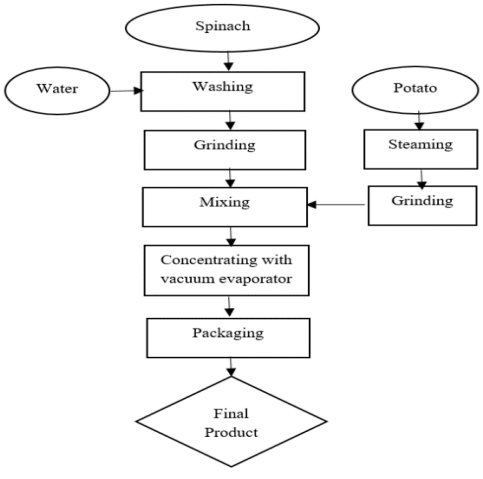

Fig 1. Flow Chart

2.2.2. Analytical methods

Viscosity was measured using a hand-held viscometer, Ametek Brookfield - American, model (XD V2TLVTJ00E00). Device parameters are 0.1 – 200rpm, 15-6,000,000 mPa.s.

Moisture was determined using an infrared hygrometer of model (AND MF-50). Device parameters: Min. Recommended Moisture Range (%MC): 0.01, Repeatability (sd) with 2g Sample: 0.05 %, Drying Temperature: 40 °C – 230 °C.

Brix Meter 0-90% Brix Meter Handheld Refractometer Home Measuring Instrument Brix Meter Brix Meter ATC Temperature.

And the Omega-3 content was determined following the AOAC 2016 (996.06) method.

Three treatment formulations and one control were used to perform sensory evaluation (Color, Smell, Structure). Products would be evaluated sensory to choose the highest preferred level products by Score sensory evaluation method.

2.2.3. Analyzing data

Experimental data analyzed and graphed on Microsoft Excel 2013. Analysis of variance (ANOVA) to compare treatments.

The experimental data was analyzed and graphed using Microsoft Excel 2013. ANOVA (Analysis of variance) was performed to compare the different treatments.

3. RESEARCH RESULTS

3.1 Survey results on the ratio of vegetables and water

Based on Table 1, it can be observed that there is a positive correlation between the percentage of vegetables and the viscosity of the puree product, as higher percentages of vegetables corresponded to higher viscosity values in mPas. Additionally, according to TCVN 5305:2008 (CODEX STAN 57 – 1981, Rev.2007), the Brix of the puree product should be between 7% and 24% of the total naturally dissolved solids content. The results in Table 1 demonstrated that the samples with ratios of vegetables to water of 150:50, 160:40, and 170:30 had Brix values greater than 7, meeting the requirement for the puree product. Moreover, statistical analysis indicated that these samples were not significantly different from each other ($p > 0.05$) in terms of Brix values.

Furthermore, Table 1 also demonstrated that there was an increase in viscosity with an increase in the percentage of vegetables, with sample 6 having the highest viscosity of 7738 mPa.s compared to sample 1, which had a viscosity of 4020 mPa.s. This suggests that the concentration of spinach increased with the increase in solid content and decrease in moisture. This phenomenon has been reported previously for tapioca meal (Abdul-Rasaq A. Adebowale, 2013), where the viscosity increased as the solid content increased and the viscometer speed decreased.

After considering the sensory quality of the product, as well as the Brix and viscosity values, sample 4 with a ratio of vegetables to water of 150:50 was chosen for further experimental surveys as it had a viscosity closest to the desired product viscosity.

Table 1. Table of viscosity criteria

Sample	Ratio	Viscosity (mPa·s)
1	120:80	4020 ± 9^{f}
2	130:70	5500 ± 26^{e}
3	140:60	6142 ± 12^{d}
4	150:50	6300 ± 15^{c}
5	160:40	7400 ± 9^{b}
6	170:30	7738 ± 9^{a}

Table 2. Table of criteria (Brix, Moisture)

Sample	Brix (%)	Moisture (%)
1	6.5 ± 0.1^{b}	93.1 ± 0.987^{a}
2	6.7 ± 0.2^{ab}	93.04 ± 0.03^{a}
3	6.8 ± 0.2^{ab}	92.3 ± 0.3^{ab}
4	7.0 ± 0.2^{a}	91.6 ± 0.2^{b}
5	7.0 ± 0.1^{a}	91.52 ± 0.03^{b}
6	7.1 ± 0.2^{a}	91.46 ± 0.02^{b}

3.2 The result of the combination of potato content in the product

According to the sensory evaluation results presented in table 3, it was observed that the three potato samples with weights of 40g, 50g, and 60g respectively, had significant differences ($p<0.5\%$) in terms of viscosity. Adding 50g of potatoes to the product resulted in the most preffered structure and flavor, with a corresponding viscosity of 4285 ± 16 mPa.s (Fig 2), moisture of 91.2 ± 0.07% (Fig 2), and Brix of 7.1 ± 0.2% (Fig 1). However, the taste was found to be similar for all three samples (40g, 50g, 60g) at a 95% confidence level.

The sensory evaluation panel did not like the sample made with 40g of vegetable concentrate because it was too dilute, and the sample made with 60g of concentrate was too thick. Additionally, adding more potatoes to the spinach mixture resulted in a lighter green color, which was not visually appealing and led to a low rating. Based on these observations, it was concluded that sample number 2 with a potato weight of 50g should be selected as the standard sample for further experiments.

Table 3. Sensory evaluation of products

Potato content (g)	Color	Smell	Structure
40	1.667 ± 0.3^{b}	2.17 ± 0.5^{a}	3.0 ± 0.3^{b}
50	3 ± 0.5^{a}	3 ± 0.5^{a}	3.5 ± 0.5^{a}
60	2.250 ± 0.4^{ab}	2.5 ± 0.5^{a}	2.3 ± 0.3^{c}

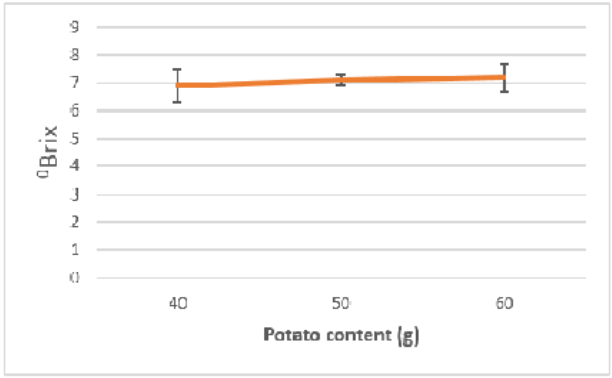

Fig 1: Fig of criteria (Brix) after adding with potato in the product

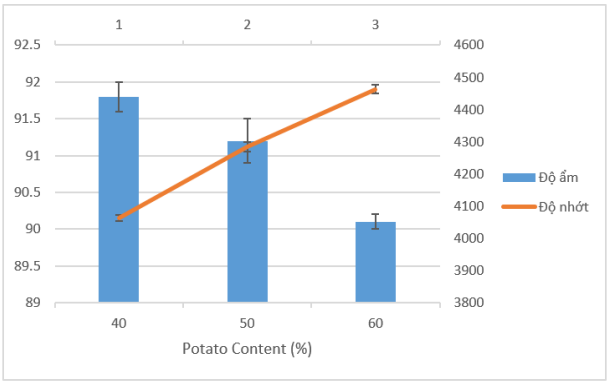

Fig 2: Fig of criteria (Moisture, Viscosity) after adding with potato in the product

3.3. The results on the effect of concentration-time on dry matter content by vacuum concentrator

According to the results in Table 4, table 5 it is clear that the taste of the product is highly appreciated when the concentration time is 20 minutes. The sensory evaluation score at this time has no significant difference with the score at 30 minutes incubation time ($p<0.5$). Additionally, the product structure was most favored when the concentration time was 20 minutes. However, there were significant differences between treatments for product structure ($p<0.5$). The sensory evaluation of color was similar to that of taste for treatments 2 and 3.

There were significant differences between treatments in Moisture, Brix, viscosity, Omega -3 results (Table 6, table 7) ($p<0.5$). Humidity, nutritional content of omega-3 are inversely proportional to temperature while Brix and viscosity are increase with decreasing temperature.

To achieve high consumer preference, it is important to retain the maximum nutritional content in the product, such as omega-3 content at 51.4 ± 0.3 mg/100g. The content of this free fatty acids is consistent with the research results of M Antonia Murcia, 1992. The total lipid content (0-61%) is determined in two processing stages with fatty acids such as palmitic, hexadecadienoic, hexadecenoic,

stearic and hexadecatrienoic, oleic, linoleic, and linolenic.

Therefore, treatment 2 will be selected to proceed the production of spinach concentrate.

Table 4. Sensory evaluation of products

Experiment	Time (minutes)	Smell	Color
1	10	1.917 ± 0.4^{ab}	2.76 ± 0.17^{a}
2	20	2.917 ± 0.5^{a}	3.37 ± 0.35^{a}
3	30	2.250 ± 0.35^{ab}	2.67 ± 0.29^{a}
4	40	1.250 ± 0.2^{bc}	1.55 ± 0.23^{b}
5	50	1.167 ± 0.7^{c}	1.4 ± 0.4^{b}

Table 5. The result after the concentration process (Structure)

Experiment	Time (minutes)	Structure
1	10	2.523 ± 0.2^{b}
2	20	3.200 ± 0.4^{a}
3	30	2.591 ± 0.7^{b}
4	40	2.432 ± 0.6^{b}
5	50	1.475 ± 0.3^{c}

Table 6. The result after the concentration process (Moisture, Brix)

Experiment	Time (minutes)	Moisture (%)	Brix (%)
1	10	92.6 ± 0.12^{a}	6.7 ± 0.2^{c}
2	20	81.04 ± 0.07^{b}	7.0 ± 0.3^{c}
3	30	79.2 ± 0.04^{bc}	7.0 ± 0.1^{c}
4	40	77.9 ± 0.17^{c}	8.1 ± 0.3^{b}
5	50	76.08 ± 0.11^{d}	9.5 ± 0.2^{a}

Table 7. The result after the concentration process (Viscosity, Omega – 3)

Experiment	Time (minutes)	Viscosity (mPa.s)	Omega – 3 (mg/100g)
1	10	5110 ± 21^{e}	52.9 ± 0.1^{a}
2	20	6283 ± 18^{d}	51.4 ± 0.3^{b}
3	30	6824 ± 9^{c}	48.6 ± 0.2^{c}
4	40	7135 ± 13^{b}	45.2 ± 0.2^{d}
5	50	7619 ± 25^{a}	40.4 ± 0.3^{e}

Omega – 3 include *α-linolenic acid* (ALA), *Eicosatrienoic* (EPA), *Docosahexaenoic acid* (DHA)

3. CONCLUSION

It seems like the experiments have yielded some optimal parameters for the spinach concentration process using a vacuum concentrator. According to the results, the vegetable-to-water ratio of 150:50, potato content of 50g, and an evaporation time of 20 minutes have resulted in a concentrated vegetable product with a viscosity of 6283 ± 18 mPa.s, humidity of 81.04 ± 0.07%, and Brix of 7.0 ± 0.3%. Moreover, the final product was tested for omega-3 content, including *α-linolenic acid* (ALA), *Eicosatrienoic* (EPA), *Docosahexaenoic acid* (DHA), and the results showed a content of 51.4 mg/100g.

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NGHIÊN CỨU SẢN PHẨM RAU BINA CÔ ĐẶC BẰNG THIẾT BỊ CÔ ĐẶC CHÂN KHÔNG

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THÔNG TIN CHUNG

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TỪ KHOÁ

Brix;
Cô đặc;
Độ nhớt.
Rau bina;

TÓM TẮT

Mục tiêu của nghiên cứu này là điều tra việc sản xuất rau bina cô đặc. Nghiên cứu đã chỉ ra rằng một số yếu tố ảnh hưởng đến quá trình cô đặc, bao gồm tỷ lệ rau và nước trong quá trình nghiền, hàm lượng khoai tây trộn vào sản phẩm và thời gian cô đặc. Sau khi thử nghiệm, các thông số tối ưu được tìm thấy là tỷ lệ rau-nước là 150:50, hàm lượng khoai tây là 50g và thời gian cô đặc là 20 phút. Sản phẩm cô đặc thực vật thu được có độ nhớt 6283 mPa.s, độ ẩm 81.04 ± 0.07% và giá trị Brix là 7.0 ± 0.3% với hàm lượng omega-3 bao gồm α-linolenic acid (ALA), Eicosatrienoic (EPA), Docosahexaenoic acid (DHA) có trong sản phẩm cuối là 51.4 ± 0.3 mg/100g.