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The Study of Citrus's Fibers Production for Power Bar and the Effect on Consumer's Acceptance

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Abstract

This research is a study into the production of citrus fiber from 4 citrus plants: pomelo, tangerines, sweet orange, and limes. Produced dietary fibers were analyzed and the amounts of fiber were found to be 58.21 %, 48.45 %, 44.90 %, and 41.70 % in the pomelo, tangerines, sweet orange, and limes, respectively. According to appropriate material supply, fiber amounts, and the production time, fiber from selected tangerines was added to a power bar product. The ingredients of the power bars were investigated and controlled based on the standard of Acceptable Macronutrient Distribution Ranges (AMDR). The nutrient energy of the power bar was analyzed, and the results showed a calorie ratio of carbohydrate 48.02 %, protein 11.40 %, and fats 40.56 %. These power bars were produced with the amount of citrus dietary fiber being added in the ratio of 5 %, 7 %, and 10%. The result showed that the power bar containing 5 % ratio of citrus's fiber had average scores for the highest of all aspects. Appearance had an average score of 8.60, color with an average score of 8.66, taste with an average score of 8.73, texture had an average score of 8.46, and finally, overall acceptance had an average score of 8.73. The amount of orange peel added to the energy bar at 7 % ratio and 10 % ratio are different from 5 % ratio with a 95 % confidence in statistics.

Introduction

In the military, cadets training in the field or on operations require quick deployment, and therefore carry dried food or canned meal. Despite the convenience of these foods, the nutritional balance is a concern. Therefore, there has been the development of Meal, Ready-to-Eat (MRE) that is not only lightweight but also has sufficient nutrition for a daily meal. This is the fundamental energy for supporting the tasks efficiently. Nevertheless, ready meals such as the power bar do not contain enough fiber; therefore, the increment of fiber in the power bar will improve cadets' health during field operations. Moreover, people in modern life are increasingly concerned about their health. The daily meals are a hot topic because the proper amount of nutritional food can balance the necessary energy and keep the body working efficiently. Consequently, the

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research about the increment of fibers in the power bar is intended to provide another choice for consumers who expect sufficient nutrition, proper energy and resolve the malnutrition problem in dieters. The power bar that increased the level of fiber from the citrus is also environmental-friendly because they utilize fruit peel which was previously a waste product from the food industry. The daily energy requirement in humans relies on all-day energy metabolism. For example, the energy of the muscle movement can be assumed from the body's size, type of movement, and the value of the Basal Metabolic Rate (B.M.R.). According to the statistical data, the average energy which is required daily for human, is categorized in the following age range; children (1-3 years) require 1,000-1,200 kcal/day; children (4-8 years) require 1,200-1,400 kcal/day; adult boy and girl (9-18 years) require 1,600-2,400 kcal/day; men (19-60 years) require 1,800-2,200 kcal/day; women (19-60 years) require 1,500-1,800 kcal/day; and the seniors men and women (older than 60 years) require 1,500-1,800 kcal/day (Bureau of Nutrition, 2020). Energy from the principal nutrients are composed of three elements, carbohydrate, protein, and fats. The ratio of these energetic nutrients is essential for nutritional balance. There is the recommendation ratio among the energetic nutrients in daily food, which is referenced by the various standard value. In this research, we refer the ratio of energetic nutrients with the Acceptable Macronutrient Distribution Ranges (AMDR) that shows the required amounts of each energetic nutrient in Table 1 (Weight Watchers Research Department, 2019).

Table 1 The requirement percentage of nutrient energy

Nutrient	Requirement percentage (%)
Carbohydrate	46 – 65
Protein	10 – 15
Fats	20 – 35

Remark: AMDR-Macronutrient Ranges and Recommendations, Weight Watchers Research Department

Fiber is the composition of the cell wall in plant-based foods. Due to the indigestible element, it cannot absorb and does not give any energy to the human body. There is 2 type of fibers, soluble dietary fiber and insoluble dietary fiber. The fiber amounts in this research are both soluble and insoluble dietary fibers. According to the study about the fiber utilization from wasted fruits and vegetables, the fiber amounts in the orange rind are about 63.7% by dry weight (Tanongkankit, 2014). Thailand's Food and Drug Administration (F.D.A.) makes the table of Thai Recommended Daily Intake (Thai R.D.I.) for Thai people older than six years old. These standard values are the references used for the nutrient calculation in the food label. It shows that the required daily intake of fiber should be more than 25 grams (Watthanataweekul, 2002).

The peel of orange-species fruit and orange can be categorized into four groups; 1) orange group 2) mandarins 3) pomelos or grapefruits and 4) common acid members (Janluay et al., 2009). As the results of fiber-contained in citrus, the fiber amounts inside the orange rind are greater than the fiber amounts in pulp. It also found that the amounts of fiber in fresh rind is high; 93.07% by weight (Saengthongpinit, 2008). Therefore, the objectives of this study are the studying of fiber preparing method and developing the ingredient of fiber added power bar. The developed power bar must meet the nutrient standard of Thai R.D.I. and be satisfying and desirable for the consumer.

Materials and methods

The experiments were composed of 3 steps; (1) Fiber preparation: the dietery fibers of four citrus plants were prepared; pomelo, tangerines, *Citrus sinensis*, and limes, and then a chemical analysis was made to determine the fiber amounts. (2) Power bar production: soybean meal was used as the main component of the power bar and adjusted an ingredient ratio for the appropriated nutrients balanced. (3) The customer's acceptance of the power bar, which added the fiber amounts by weight ratio 5%, 7%, and 10% was evaluated by CLT method. The popular level is a quantitative expression by 9- point hedonic scale.

1. Fiber preparation from orange-species fruit

There are 4 main processes of the fiber extraction from orange rind, (1) wet milling process, (2) washing process, (3) drying process, and (4) dry milling process, respectively (Larrauri, 1997). The experiment proceeds as follows (Pichaiyongvongdee & Rattanapun, 2014). Each of step were shown in the Fig.1

1.1 Wash and cut each type of orange rind into a rectangle shape with a small size (1 x 1 cm).

1.2 Decrease the bitter taste by soaking the rind pieces in sodium chloride solution and adjust the pH value to 7 with the concentration 1:10 (w/v) for 24 hours.

1.3 Water steaming at 80˚C for 10 minutes.

1.4 Heating at 60˚C for 6-8 hours. The orange rind will be in a dehydrated state.

1.5 Finely milling the rind pieces by herb grinder and

sieving the powder using 60 mesh screens.

1.6 Determine the amounts of dietary fiber by analyzing fiber powder with the In-house method (CH-TH-076) base on AOAC (2016) at the Central Lab (Thailand) company.

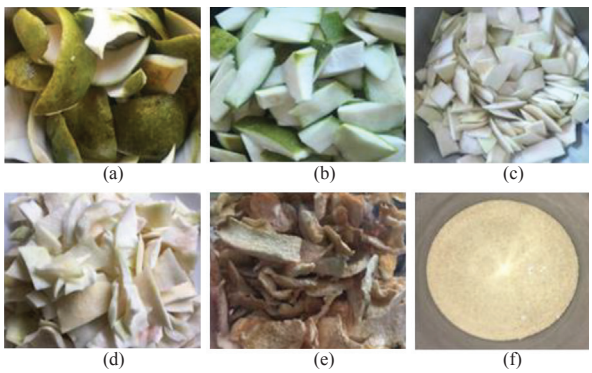

Fig. 1 Physical appearance during the fiber extraction process (pomelo's fiber powder (a) pomelo peel, (b) pomelo peel cut of rind into a rectangle shape, (c) pomelo peel soaked in sodium chloride solution, (d) steamed at 80°C for 10 mins pomelo peel, (e) hydrated pomelo peel, (f) pomelo's fiber powder

2. Production and development of power bar using the prepared fiber as a base ingredient

2.1 The main components of a power bar, butter wheat, and soybean meal were adjusted for the appropriated ingredient recipe. The ingredient of the power bar recipe performed the weight ratio as 100% total compositions. According to the balance of mixing energetic ingredients in which protein ingredient (50% soybean meal content) was controlled to be constant, carbohydrate and fats ingredients were varied in 3 types of ingredients, as shown in Table 2.

Table 2 Various ingredients of wheat and butter contents in power bar production

Ingredients no.	Wheat (%)	Butter (%)	Soybean meal and others. (%)
1	30	20	50
2	35	15	50
3	40	10	50

2.2 The method of chemical property analysis such as a moister content analysis (AOAC., 2019), ash contents analysis (AOAC., 2019), carbohydrate contents analysis (In-house method CH-TH-169 base on method of Analysis for Nutrition Labelling of Sullivan & Carpenter, 1993), protein contents analysis (In-house method CH-TH-042) and fats contents analysis (AOAC., 2019) are supported by the laboratory test at the Central Lab (Thailand). The test results were compared and selected the ingredient recipe, which had a nutrient value, mostly like the requirement of the daily nutrient standard. Consequently, ingredients no. 3 was applied as the base recipe. The basic composition of the power bar which has a nutrient energy ratio based on AMDR standard. Add the fiber powder into the power bar until the fiber amounts are sufficient for the daily requirement amount, 25-20 grams. Fig.2 shows the appearance of the base products approximately 12-13 grams per piece.

Fig. 2 The appearance of base products

3. Customer's acceptance investigation

Made the questionnaire style survey about the customer's satisfaction with the power bar, which added the fiber amounts by weight ratio 5%, 7% and 10%.

3.1 The base ingredient of the power bar was added the dietary fiber by weight ratio of 5%, 7% and 10%. This weight ratio is calculated by comparing the weight of the orange rind and the weight of the products. The products are a circular disc with a diameter of 4 cm. The weight per piece is 12 grams. The products are baked in the oven at 180˚C heat for 10 minutes. Fig. 3 shows the appearance of the final products. These fibers added power bars were surveyed for the degree of consumer satisfaction. The degree of consumer satisfaction will be verified by the 9-point hedonic scale method. The popular scores are averaged, and a statistical analysis was performed.

Fig. 3 The samples of final products with the fiber weight ratio 5%, 7% and 10%, respectively

3.2 The survey, the consumer acceptance for fiber added power bar was verified by the Central Location Test (CLT) method. The popular level is a quantitative expression by 9- point hedonic scale (1 = least popular to 9 = most popular). The details of the questionnaires were the opinion about the product characteristics, appearance, color, smell, taste, and the overview image. The survey was given to 30 subjects with the 3 types of products varied in fiber amounts; 5 %, 7 % and 10 % by weight ratio. The survey results were conducted into a data analysis program SPSS (Kongkaew et al., 2019). The analysis of variance (ANOVA) and multiple comparisons, Duncan's new multiple range test methods, were applied with the condition $p<0.05$.

Results and discussion

1. The process of reducing the bitterness in orange peels

In the production of citrus's fiber 4 citrus plants; pomelo, tangerines, sweet orange, and limes, the bitter taste was reduced by a process of soaking. The citrus peel was soaked in the 10% (w/v) NaCl solution with pH 7 for 24 hours then steamed for 10 minutes. The fiber of pomelo was found to be the most bitter. Because the bitter taste in pomelo peel composed of the derivative of triterpenes called Limonin ($C_{26}H_{30}O_8$), which readily dissolved in acetone or chloroform but were only slightly soluble in aqueous (Maier et al., 1977). The result was consistent with the investigation about the production of fiber powder from pomelo's internal peel by Pichaiyongvongdee & Rattanapun (2014). The verified result of the physical properties of citrus's fiber found that bitterness of pomelo is in Limonin which can be reduced by using 1% NaCl. The result showed that the bitterness can be reduced for 10.3% compared to 7.74% of bitterness reduction using pure water, the results did not have any statistical significance in the difference. Therefore, this research used fiber powder from the mandarin orange peel with high fiber amounts of 48.45%. Moreover, the bitter test in mandarin orange was naringin that could be dissolved in warm water readily. In contrast, the hard-dissolved substance, limonin mainly found in the seed of mandarin orange (Sansawat, 2006).

For the application of a hot air oven in the drying process, the results of the drying time and temperature by Pichaiyongvongdee & Rattanapun (2014) showed that the higher temperature could reduce the drying time, the fiber amounts could be reduced. While drying the process with high temperature, the structure of the cell's wall was damaged, and the absorption performance in both water and oil was increasing (Gould et al., 1989). This effect is also found in Chinnasarn et al. (2015) in the drying process with low temperature, a long time for drying reduced sugar in pectin substance and the performance of water conservation was decreased. According to the drying process for apple peel by Constenla et al. (2002), the structure of fiber did not show any change at drying temperature 60-80˚C. However, at the drying temperature 105˚C, the amounts of pectin are reduced significantly. Consequently, this research controlled the drying temperature at 60˚C and dying time for 6 hours. All types of orange peel were dried entirely and became a dark color, as shown in Fig. 5.

Fig. 5 The appearance of each citrus peel after dried entirely (a) dried pomelo peel, (b) dried mandarin orange peel, (c) dried sweet orange peel, (d) dried lime peel

After the drying process, each of orange peel was finely milled by the herb grinding machine, then make a sieved the powder by 60 mesh screens. Each of fiber powder was shown in Fig. 6

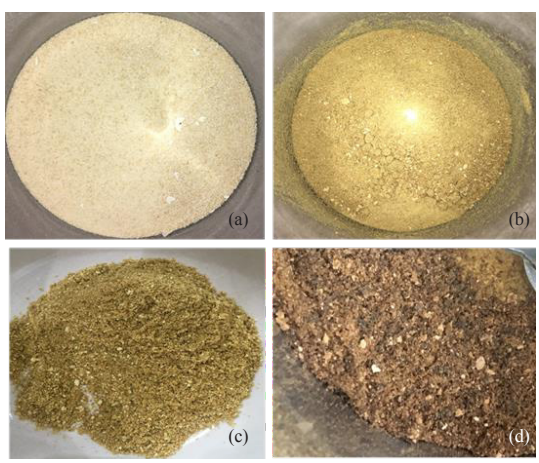

Fig. 6 Fiber powder from the citrus peel (a) pomelo's fiber powder, (b) mandarin orange's fiber powder, (c) sweet orange's fiber powder, (d) limes's fiber powder

The amounts of dietary fiber were measured at the Central Lab (Thailand) company. The results have shown the amounts of fiber from 100 grams of sample. The percentage of weight ratio was summarized in Table 3.

Table 3 Summary the fiber amounts from 4 types of citrus peel

Type of citrus peel	Dietary fiber amounts (%)
Sweet orange	44.99
Mandarin orange	48.45
Pomelo	58.21
Lemon	41.70

The comparison results from 4 types of citrus peel found that the highest-fiber amount was pomelo (58.21%), following by the mandarin orange (48.45%), sweet orange (44.99%), and the lowest fiber amounts were lemon (41.7%). In the investigation of dietary fiber from the pomelo peel, 92% was a water-insoluble fiber. The ratio between soluble and insoluble fiber varied from 1: 5.9 to 1:12.7. It depends on the pomelo species and the production process (Saengthongpinit, 2008). The results corresponding with the research by Pichaiyongvongdee & Rattanapun (2014) that showed the fiber amounts from pomelo was higher than other fruits, peach, pear, sugarcane, the pericarp of cumin, apple, banana, carrot and the other citrus species such as grapefruit, mandarin orange and lemon. However, the fiber amounts from pomelo in this study were lower than Saengthongpinit (2008). In an experimental result, the amount of fiber in pomelo depends on the processing method. Fiber amounts produced by the boiling and heating process tend to lower than the producing by non-heating. The fiber amount from boiled and heated pomelo peel is lower than fresh pomelo peel (Saengthongpinit, 2008).

2. The investigation of power bar base ingredients and chemical properties analysis results

Three base ingredients were verified for the quantity analysis. The weights of moisture, ash, carbohydrate, fat and protein in power bar 100 grams are shown in Table 4.

Table 4 The chemical analysis of 3 base ingredients of the power bar

Chemical analysis	Power bar (g/100 g)		
	No. 1	No. 2	No. 3
Moisture	5.27	7.34	7.05
Ash	1.28	0.98	1.72
Carbohydrate	58.83	56.84	68.85
Protein (%N x 6.25)	11.47	13.50	11.81
Fat	23.15	21.34	10.57

Compared to the AMDR standard, nutrients energy (carbohydrate, protein and fat) in table 5 were calculated for the energy ratios by using the energy rate, 4 kcal/g in carbohydrate and protein, 9 kcal/g in fats. Each of the base ingredients in the power bar showed the ratios of nutrients energy compare to the AMDR standard in Table 5.

Table 5 The results of energetic nutrient ratios

Nutrient	Power bar (%)			The AMDR's standard amounts (%)
	No. 1	No. 2	No. 3	
Carbohydrate	48.06	48.02	65.92	46 – 65
Protein	9.37	11.40	10.11	10 – 15
Fats	42.56	40.56	22.77	20 – 35

The comparison between the ratios of nutrients energy and the daily-requirement energy, the AMDR standard value in Table 5, the base ingredient No. 3 found the most consistent with the AMDR standard. Therefore, this research will apply this base ingredient to the fiber-adding process.

3. The investigation about the consumer acceptance of the power bar added the citrus fiber by weight ratio 5%, 7% and 10%

The consumer's acceptance was evaluated by Central Location Test (CLT) method. The popular level is a quantitative expression by 9-point hedonic scale (1 = least popular to 9 = most popular). The questionnaires will be about the opinion about the product characteristics, appearance, color, smell or flavor, texture and the overview image given to 30 subjects. The results of consumer's acceptance for the power bar, which added the 3 fibers ratios, are summarized in Table 6.

Table 6 The results of consumer satisfaction in fiber addition products

Evaluated Item	The percent amounts of citrus's fiber from an orange peel added to the products		
	5%	7%	10%
Appearance	8.60 ± 0.56^{a}	7.76 ± 0.72^{b}	7.23 ± 1.16^{c}
Color	8.66 ± 0.47^{a}	7.76 ± 0.85^{b}	6.86 ± 1.35^{c}
Flavor	8.73 ± 0.44^{a}	7.63 ± 0.99^{b}	6.50 ± 1.35^{c}
Texture	8.46 ± 0.57^{a}	7.33 ± 0.92^{b}	6.06 ± 1.98^{c}
Overall acceptance	8.73 ± 0.44^{a}	7.80 ± 0.88^{b}	6.96 ± 1.1^{c}

Remark: a-c means the average data in the same rows which have a different character. The statistical significance of the difference was a 95% confidence interval

The average score of flavors from the power bar with amounts of citrus's fiber 5%, 7% and 10% is between medium popular much more popular with the score of 8.73, 7.63 and 6.50, respectively. The popular score of

5% ratio fiber amounts had the highest average score of flavors. The comparison among 3 ingredient ratios showed that the 7% ratio and 10% ratio are different in statistical significance from 5% ratio at 95% confidence interval. According to the removal of naringin in mandarin orange peel did not completely do, the addition fibers in the power bar increased the bitter taste. In the investigations by Attavanich & Anprung (2003) found that, although naringin in mandarin orange peel was soluble in warm water, the aqueous extraction and pH adjustment method could reduce the bitter teste just slightly ($P \leq 0.05$).

The average score of texture from the power bar with amounts of citrus's fiber 5%, 7% and 10 % was found between the range of least popular to more popular in the score 8.46, 7.33 and 6.06, respectively. The popular score of 5% fiber amounts had the highest average score with regards to texture. The comparison among 3 ingredient ratios shown that 7% ratio are 10% ratio are different in statistical significance from 5% ratio at in 95% confidence interval. The results showed that the increase of fiber ratio increased the hardness of texture. The dried fiber could absorb the water contents in products (Siwnguan, 2017). Increasing hardness affected the consumer's acceptance in the point of view of texture was decreased. Consequently, a low fiber addition ratio received higher acceptance scores than the power bar with high fiber addition ratios.

The average score of overall acceptance from the power bar with amounts of 5%, 7% and 10% citrus's fiber was found between the range of least popular to more popular in the score 8.73, 7.80 and 6.96, respectively. The popular score of 5% fiber amounts had the highest average score of the overall acceptance. The comparison among 3 ingredient ratios shown that 7% ratio and 10% ratio are different in statistical significance from 5% ratio at in 95% confidence interval. This research found that the 5% fiber addition of power bars got the highest score in all points of view. The acceptance scores seem to be decreased when the added fiber ratio in the power bar was higher than 7%.

Table 7 The results of the acceptable total score in the additional fiber products

No.	Power bar	Average of the acceptable total score
1.	Fundamental formula with orange fiber 5%	8.73 ± 0.44^{a}
2.	Fundamental formula with orange fiber 7%	7.80 ± 0.88^{b}
3.	Fundamental formula with orange fiber 10%	6.96 ± 1.18^{c}

Remark: a-c means the average data in the same rows which have a different character. The statistical significance of the difference was a 95% confidence interval

Table 6 shown the summarized total acceptance scores of power bar due to the base ingredients with 5%, 7% and 10% orange fiber. They were in the range of little popular to much more popular with the scores 8.73, 7.80 and 6.96, respectively. The power bar that added 5% citrus peel fiber powder has the highest total score and the comparison result of the differences among 3 ratios shows that the 7% and 10% has the statistical significance in the difference with 5% in 95% confidence interval. Consequently, fiber additional 5% of the power bar was accepted due to the highest average scores. It was good in appearance, appropriate color, mild taste and crunchy. This delicious sensation caused the best taste results. Then the sample with the highest score of satisfaction consumers was analyzed for the total energy, ratios of energetic ingredients (carbohydrate: protein: fats) and dietary fiber at the Central Lab (Thailand) company. The results were shown in Table 8.

Table 8 The analysis results of the highest score of the satisfaction consumer product

Chemical analysis	Powerbar with 5% orange fiber (%)	Requirement ratio of AMDR Standard
Carbohydrate	56.84	55-60 %
Protein	13.50	10-15 %
Fats	21.34	< 30 %
Total energy (in 100 grams)	473.42 kcal	-
Fiber	6.22	25-30 g/day

Using these products instead of regular food, serving size for daily required energy will be concerned. Although the daily requirement of total energy depends on the personal activity, 2,000 kcal is the typical average value that was converted to the weight of 1 meal, 150 grams with the equivalent energy 710.13 kcal and including fiber weight 9.33 grams.

Conclusion

The production of fiber analysis from 4 types of citrus fruit, sweet orange, mandarin orange, pomelo, and lemon, which had the drying process for an orange peel 300 grams, thick peel of pomelo and lemon required dehydrating time longer than 6 hours. Whereas the thinner peel, sweet orange, and mandarin orange, in which water absorption is limited, required 6 hours for dehydrating. All dehydrated orange peel was dried entirely, and their color became dark green. Dehydration temperature was stable at 60˚C during the drying process.

The analysis results from Central Lab (Thailand) showed the fiber amounts from 4 types of citrus. Fiber powder from pomelo peel has the highest fiber amounts of 58.21 %, followed by 48.45 % in sweet orange and 44.99 % in mandarin orange while lemon has the lowest fiber 41.70 %.

In conclusion, the results of the investigation about the basic components of a power bar, which has an energetic nutrients ratio based on the AMDR standard, the fundamental formula which composes of 40% wheat, 10% butter and 50% soybean meal and others showed that the ratios of the energetic nutrient is similar to the AMDR standard. In the power bar 100 grams, the study found 65.92% carbohydrate, 10.11% protein and 22.77 % fats.

The results of the investigation about the fiber addition ratio and the verification of consumer satisfaction by a 9-point hedonic scale showed that the power bar, which added 5 % fiber, had the highest in an average score of an appearance, color, smell, flavor, texture and the overview image. The difference results among 3 gradients ratio shown the ingredient ratios 7 % and 10 % have the statistical significance differed from ingredient ratio 5 % in 95 % confidence interval. Consequently, fiber additional 5% of the power bar was acknowledged for the highest average scores and the best of taste evaluation.

Acknowledgments

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