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Original Research Article

Effect of Cooking Conditions on the Nutritional Composition of Some Cooked Dry Beans

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ABSTRACT

Dry beans are cooked before consumption. The heat from cooking helps to modify the structure and chemical composition of some nutritional compounds, particularly the protein complexes and bound phenolic compounds, which enables them to be digested easily. Some chemical compositions may be modified, and nutritional value may be changed. Two dry beans (black and red kidney) were selected to be cooked under two different cooking conditions (conventional steam and saturated steam under pressure) for this study. Therefore, the main objective of this presentation was to determine the effect of cooking conditions on the nutritional properties of these two cooked dry beans. For preliminary purposes, both types of dry beans were subjected to an 8-hour soaking period prior to cooking. The conventional steaming time for black beans was 35 minutes and 45 minutes for red kidney beans at 100°C under normal atmospheric pressure, whereas the pressure steaming time was 10 minutes for black beans and 20 minutes for red kidney beans at 10psi above atmospheric pressure. The nutritional value of soaked beans was also determined. Before the determination of nutritional value, both types of beans were ensured that they were equally cooked by textural analysis (hardness measured by a puncture test). The average puncture force of each cooked bean was around 360-380gf, which was considered soft and palatable. For nutritional value, the results of crude protein, crude fat, and crude ash content in cooked beans obtained from the two different cooking methods proved no significant difference. This occurred in both types of beans. However, cooking caused some changes in crude fiber content of dried beans. Especially in red kidney beans, the saturated steam under pressure cooking method led to a significant reduction in their crude fiber content. Hence, the difference in nutritional values which is affected by cooking conditions in these two types of bean (comparing with soaked beans) is essential to prove which cooking method provides utmost benefits in terms of overall nutritional values provided by cooked beans.

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INTRODUCTION

Nowadays, whole-food plant-based diets become popular worldwide since their nutritional value has great association with human health benefits such as lowering blood sugar level, improving kidney function, as well as preventing cardiovascular diseases, obesity, diabetes mellitus and cancer (Cakir et al., 2019). Dry beans (often called grain legumes) are one of those plant-based foods which are likewise proven to provide many health benefits for humans due to their abundance in nutritional values, including protein, fiber, micronutrients, and phytochemicals (Messina, 2014). By definition, legumes are any plant from the *Fabaceae* family that include its leaves, stems, and pods, whilst pulses are an edible seed from a legume plant according to the Food and Agriculture Organization (FAO). For instance; pea pod is "legume", but the pea is "pulse". In scientific term, many legumes are called "*Phaseolus vulgaris*", which contain around 18,000 species worldwide and are various in terms of shape and color. Due to this phenomenon, each bean has their specific names according to their unique appearance and morphology. For instance, some red beans are called "kidney beans" because of their red color and elliptical shape which are similar to human kidney, whereas, some black beans are called "black turtle beans" because of black color and small, oval-shaped. Nevertheless, both raw red beans and black beans have very similar property in terms of nutritional composition, especially protein, dietary fiber, vitamins, minerals, antioxidants and so on (Gonzalez-Perez et al., 2019).

However, the main issue is that raw beans contain many anti-nutritional compounds, for instance; lectins, tannins, phytic acid and oligosaccharides (Carbas et al., 2020). Anti-nutritional compounds could impair digestion and prevent absorption of minerals which could be detrimental to health. Hence, this is the reason why dry beans are necessarily cooked before consumption since cooking could help to reduce or get rid of anti-nutritional compounds. Moreover, the heat from cooking likewise helps to modify the structure and chemical composition of some nutritional compounds, particularly the protein complexes and bound phenolic compounds, which enables them to be digested easily (Sangsukiam et al., 2022). Since some chemical compositions may be modified, the nutritional value of cooked beans could also be changed.

Both conventional steam and saturated steam under pressure cooking methods were chosen in this particular study because they are one of the healthiest household cooking methods which apply gentile heat and do not burn or scorch food comparing to other dry heat cooking methods (Jacqueline et al., 2019). The major difference between conventional steam and saturated steam under pressure cooking method is the time of cooking process. The conventional steaming is a moist-heat cooking method which the boiling water vaporizes into the steam and comes into direct contact with food. The conventional steam cooking typically processes at the water boiling point or 100°C under atmospheric pressure (Rutala et al., 2008). In contrast, the saturated steam under pressure is usually processed at more than 100°C and under pressure in pressure cooker to accelerate cooking and getting rid of all microorganisms including their spores. The increase in pressure above the atmospheric pressure enables steam to reach higher temperatures. The extra pressure elevates the boiling temperature of water, in fact, around 20°C higher which effectively increases its heat content, killing microorganism ability, and subsequently leads to much shorter cooking time (Rutala et al., 2008). Nonetheless, little information was genuinely known about the effects of these two cooking methods on the nutritional value and compositions of dry beans. Therefore, the main objective of this study was to determine the effect of cooking conditions on the nutritional properties of cooked black and red kidney dried beans, as well as to compare the effect of conventional steam and saturated steam under pressure cooking methods on their nutritional compositions.

MATERIALS AND METHODS

Materials and Chemical Reagents

The two varieties of dry beans, Black beans and Red kidney beans were obtained from the "TOPS Market" supermarket in Bangkok, Thailand. All chemicals used in this experiment were analytical grade. Boric acid (Ajax Finechem Co., Ltd, New Zealand), Ethanol (Qrec Chemicals, New Zealand), Hydrochloric acid (Qrec Chemicals, New Zealand), Kjeblet catalyst (Oskon Co. Ltd, Thailand), Methyl red indicator (Merck, Germany), Petroleum Ether (Qrec Chemicals, New Zealand), Reagent grade concentrated. sulfuric acid (Qrec Chemicals, New Zealand), Sodium hydroxide (Ajax Finechem Co., Ltd, New Zealand).

Preparation of soaked and cooked beans

Both black beans and red kidney beans were soaked in water in ratio of 1:10 for 8-hour period to make sure that both beans contained at least 50% of moisture content prior to cooking. Then, both soaked beans were subjected to two different cooking methods including conventional steaming using a household steaming pot and saturated steam under pressure using a pressure cooker (HOM-12LC58, Homemate, Thailand) with an aid of a stainless steel mesh hole tray to prevent the beans from becoming soggy. The cooking time for both bean samples was also determined specifically to make sure that both beans are equally cooked for all treatments or cooking methods by using texture or hardness of beans as criteria. The conventional steam cooking time for black beans was 35 minutes and 45 minutes for red kidney beans at 100°C under normal atmospheric pressure,

Table 1. The average puncture force (gf) of soaked and cooked beans

	Black-Soaked	Black-CS*	Black-PS*	Red-Soaked	Red-CS*	Red-PS*
Number of samples	15	15	15	15	15	15
Average value	1559.84	361.43	364.63	1553.13	377.95	377.34
S.D.	166.11	85.81	63.91	173.43	82.54	78.33
Maximum value	1839.31	514.88	445.12	1907.22	501.32	537.00
Minimum value	1242.83	222.83	213.53	1222.86	225.97	221.26

*CS = Conventional steaming, PS = Pressure steaming

whereas the saturated steam under pressure cooking time was 10 minutes for black beans and 20 minutes for red kidney beans at 10psi above atmospheric pressure, respectively (Xu et al., 2008).

Textural Analysis of soaked and cooked beans

The hardness by a puncture test of both soaked and cooked black beans and red kidney beans were measured using a TA XT2i texture analyzer (Stable Micro systems Co; Ltd, Godalming, UK). A circular, flat faced steel punch (so-called the cylindrical probe) with 2mm size was used to compress the center of the bean with 50% strain. Random 15 pieces of bean were selected to determine the average puncture force (g_f) of each treatment including both soaked and cooked beans. The force at the peak of the puncturing process was recorded and used to indicate the degree of hardness of each specific bean (Bourne, 1972).

Determination of proximate compositions

The nutritional compositions, in both soaked and cooked black and red kidney beans, including the moisture, crude protein, crude fat, crude fiber, ash and total carbohydrates were determined according to AOAC (2006). Moisture content was determined using the oven-dry method (Memmert UN 30 plus, Germany) at 105°C. Crude protein was determined using the Kjeldahl method with a digestion unit (K-324, Buchi, Switzerland) and a distillation unit (K-424, Buchi, Switzerland) and calculated with conversion factor of 6.25. Crude fat was determined using the Soxhlet extraction method (Gerhardt, Germany) with petroleum ether as a solvent. Crude fiber was determined by boiling beans in acid and base solutions. Crude ash was determined by burning beans in a muffle furnace (CWF 1200, Carbolite Gero, UK). Total carbohydrates content was determined by difference which subtracts the total percentage compositions of moisture, protein, fat, and ash contents from 100 as details in Sritongtae et al., 2017.

Statistical analysis

Experiments were carried out with completely randomized design. Statistical analysis was determined using the SPSS software for Windows (version 22). Significance of the values was assessed using 95% confidence interval. The comparison of means was done using Tukey's test at $p<0.05$ significant difference.

RESULTS AND DISCUSSION

Textural analysis of soaked and cooked beans

Generally, the average hardness of fully cooked beans for *Phaseolus vulgaris* or common bean was 3.75 N or 382.39 g_f (Kwofie et al., 2020). In this study, the average puncture force of cooked black and red kidney beans by both cooking methods was around 360-380 g_f as shown in Table 1, which resemble the average hardness as mentioned by literature. Hence, the cooked beans were considered as soft, palatable, fully and equivalently cooked for all cooking methods. Soaked beans were difficult to chew and improbable to consume since the average puncture force was approximately 1550 g_f for both soaked black and red kidney beans, which was almost five times harder than the cooked beans. Apart from the determination of cooking time, the textural analysis of cooked beans was also carried in order to make sure that the nutritional value or the proximate compositions of cooked beans were comparable for all treatments, as well as to avoid biases.

Proximate compositions for black and red kidney beans

Table 2 shows that the moisture content in both black and red kidney beans was significantly higher in conventional steaming than saturated steam under pressure method at $p<0.05$. This phenomenon may occur due to the longer cooking time for the conventional steaming method, which resulted in higher water uptake of the conventional steamed cooked beans. In contrast, the cooking time for saturated steam under pressure cooking method was relatively shorter, plus, after cooking was done, the steam pressure was released immediately from the electric pressure cooker. Hence, the sudden release of steam in the end could be the reason why the moisture content was reduced and significantly lower in the pressure steam cooked beans than the conventional steam counterparts (Richardson et al., 2002). Moreover, the difference in moisture content could cause the amount of total carbohydrates to be significantly higher in the pressure steam cooked beans than the conventional steam counterparts at $p<0.05$ for both black and red kidney beans in wet basis calculations. As a consequence, the amount of calories was likewise significantly higher in the pressure steam cooked beans than the conventional steam cooked beans at $p<0.05$ since the total carbohydrates in the pressure steam cooked beans were higher when calculated by the difference method.

No significant increase in crude fiber at $p<0.05$ was found in cooked black beans as presented in both Table 2 and Table 3. The slight increase could occur due to the modification of the structure of bean tissue and cell walls which enhances more release of some specific compounds, especially the insoluble dietary fiber compounds such as lignin and cellulose (Chang et al., 1990). Furthermore, pectin was also increased partially as a result of the cooking process. The middle lamella of bean cell walls consist of pectin and its main role was to strengthen the bean tissue. Cooking genuinely causes softening and disintegration of the bean tissue, thus, more pectin could be released in process (Belitz et al. 2009). However, it was reported that hemicellulose compound was significantly and exceptionally reduced due to pressure cooking (Rehinan et al., 2004). Thermal-induced process causes hemicellulose to lose its branch structure (Vidal-Valverde et al., 1991). Hence, this could be the main reason why the amount of crude fiber content was significantly lower in pressure steamed red kidney bean than in soaked red kidney bean at $p<0.05$ as indicated in Table 3 (in raw seed), which is opposite to cooked black beans. The exposure to extreme degree of heat plus pressure for 20 minutes could cause severe loss in hemicellulose, which subsequently caused overall reduction of total crude fiber as consequence. Therefore, this phenomenon could explain why the effect of cooking conditions was different in black beans and red kidney beans. Cooking time could play a major specific role in the modification of some chemical compounds and the complexity of bean tissue and cell

wall structure (Vasishtha et al., 2013).

Table 2. Proximate compositions of black bean and red kidney bean (w.b.)

Components (% wet basis)	Black Bean (g/100g cooked beans)			Red Kidney Bean (g/100g cooked beans)		
	Soaked	Conventional Steaming	Pressure Steaming	Soaked	Conventional Steaming	Pressure Steaming
Moisture	56.39±0.98^{bc}	58.60±0.45^{ab}	55.47±0.75^{c}	57.19±0.32^{bc}	60.27±0.21^{a}	56.12±1.08^{bc}
Crude Protein ^{ns}	10.23±0.24	10.66±0.56	10.63±0.69	9.69±0.21	9.05±0.11	9.19±0.62
Crude Fiber	3.16±0.82^{b}	4.33±0.49^{ab}	4.28±0.16^{ab}	5.17±0.16^{a}	4.54±0.06^{ab}	3.71±0.13^{ab}
Crude Fat ^{ns}	0.38±0.13	0.34±0.08	0.26±0.13	0.40±0.05	0.33±0.01	0.22±0.08
Crude Ash ^{ns}	1.65±0.24	1.62±0.16	1.49±0.04	1.43±0.00	1.53±0.29	1.70±0.08
Total Carbohydrates*	31.36±0.84^{ab} ^{c}	28.80±0.12^{c}	32.16±0.14^{ab}	31.30±0.48^{ab} ^{c}	28.84±0.62^{bc}	32.80±1.70^{a}
Energy (Kcal)	169.72±3.61^{a} ^{b}	160.81±2.03^{bc}	173.48±2.19^{a}	167.52±1.52^{a} ^{b}	154.48±1.92^{c}	169.89±3.59^{ab}

Values presented as mean ± standard deviation
*Estimated by difference using replicated values (100 – Moisture + Protein + Ash + crude fat).
Different letters across rows shows mean values that are significantly different at p<0.05 using Tukey mean comparison.

Table 3. Proximate compositions of black and red kidney bean (raw seed)

Components (%)	Black Bean (g/100g Raw seed)			Red Kidney Bean (g/100g Raw seed)		
	Soaked	Conventional Steaming	Pressure Steaming	Soaked	Conventional Steaming	Pressure Steaming
Moisture ^{ns}	13.09±0.00	13.09±0.00	13.09±0.00	12.52±0.00	12.52±0.00	12.52±0.00
Crude Protein ^{ns}	20.33±0.48	20.72±1.08	19.79±1.27	20.73±0.45	19.04±0.22	17.89±1.20
Crude Fiber	6.28±1.62^{c}	8.41±0.95^{abc}	7.96±0.30^{abc}	11.05±0.35^{a}	9.55±0.13^{ab}	7.23±0.25^{bc}
Crude Fat ^{ns}	0.75±0.26	0.65±0.16	0.49±0.23	0.85±0.11	0.70±0.04	0.43±0.17
Crude Ash ^{ns}	3.28±0.48	3.15±0.30	2.78±0.08	3.06±0.00	3.21±0.61	3.30±0.16
Total Carbohydrate*	62.56±0.26^{b}	62.40±0.63^{b}	63.86±1.13^{ab}	62.85±0.35^{ab}	64.54±0.86^{ab}	65.86±1.22^{a}
Energy (Kcal) ^{ns}	338.25±0.58	338.30±0.45	338.96±1.50	341.91±0.53	340.55±2.29	338.86±1.44

Values presented as mean ± standard deviation
*Estimated by difference using replicated values at wet basis (100 – Moisture + Protein + Ash + crude fat) and then converted to raw seed.
Different letters across rows shows mean values that are significantly different at p<0.05 using Tukey mean comparison.

In terms of crude protein, crude fat, and crude ash, the difference between cooked beans and soaked beans were not significant at p<0.05 for both black bean and red kidney bean as presented in Table 3 (in raw seed). The heat and pressure induced by the conventional steam and saturated steam under pressure cooking methods might not be adequate to destroy macronutrients in this particular study. Especially for crude fat, the beans already contain very tiny amount of fat in general. Thus, these cooking methods had no significant effect on crude fat at p<0.05 since steam cooking does not involve the application of fat and oil within the process. Additionally, in raw seed data, the moisture content is not relevant. This could well be the reason why the total carbohydrates and calories are not significantly different at p<0.05 between soaked and cooked beans (for each bean species) in the raw seed data as in the wet basis data presented in Table 2. All in all, according to the data presented in both Table 2 and Table 3, both black and red kidney beans could be either cooked by conventional steaming or saturated steam under pressure methods to maintain nutritional values since the majority of their nutritional compositions were not found to be significantly different at p<0.05 among the two cooking methods comparing to soaked beans.

CONCLUSIONS

The saturated steam under pressure cooking method caused significant decrease in crude fiber of red kidney beans at p<0.05. Unlike the black beans, both conventional steaming and pressure steaming led to the increase in crude fiber content although the difference was not significant at p<0.05. This contradiction suggests the possibility of future studies or further investigations on the fiber of cooked dry beans to determine the underlying mechanisms regarding this phenomenon, for instance, the dietary fiber and some specific fiber compounds which might be changed due to the effect of these cooking methods. Apart from crude fiber, significant differences in nutritional compositions were not found in both black and red kidney beans between the two cooking methods and the control (soaked beans) at p<0.05. Therefore, both conventional steam and saturated steam under pressure cooking methods could be beneficial in terms of maximizing nutritional value or retaining the nutrients of cooked dry beans for utmost health benefits upon consumption, considered that steaming is already one of the healthiest household cooking methods.

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