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THE INFLUENCE OF THE DEGREE OF MATURITY AND THERMAL PROCESSING ON THE CONTENT OF B VITAMINS IN BEEF

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Abstract: The aim of the study was to assess the content of B vitamins in various culinary elements of raw beef with differing degree of maturity. The types of thermal processing chosen for the study were: frying, grilling and/or roasting. The study material consisted of meat purchased in meat industrial plants immediately after the slaughter of animals at the age of 20-25 months. There were 5 culinary elements chosen for the study: topside spread, tenderloin, rump cut, shoulder and silverside, which were vacuum packed directly after the slaughter and kept refrigerated at 1°C in order to obtain different degrees of maturity (5, 10 and 15 days). It has been shown that beef is a good source of vitamin B_{12} and a poor source of other B vitamins, i.e. thiamine (B_1) or riboflavin. Topside spread and shoulder contained the least of vitamin B_{12} and niacin (vit PP), however, a considerably higher content of these vitamins was observed in tenderloin, rump cut and silverside. Additionally, the content of thiamine (vit B_1), riboflavin (vit B_2) and vit B_6 varied considerably in different culinary elements of beef, however, it did not depend on the curing time.

Key words: beef, curing time, thermal processing, the content of B vitamins.

Introduction

Meat is known to be a source of elemental nutrients (mostly protein) as well as other biochemical compounds that play an important role in maintaining human health [1,2].

The elements that draw special attention are B vitamins, especially given the fact that they are scarce in the diets of Poles [3,4]. Their content in animal products is quite varied and it depends on the type of meat as well as fat, muscle and connective tissue content. The highest content of thiamine (vit B_1) can be observed in the muscle tissue, whereby, depending on the type of meat its content varies from about 0.06 mg/100g (fish meat), 0.05 – 0.1 mg/100 g (beef and poultry) to about 1 mg/100 g (pork). The content of riboflavin (vit B_2) is the highest in veal (0.3 mg/100 g), then in beef (0.08 – 0.26 mg/100 g), pork (0.2 mg/100 g) and poultry (0.15 mg/100 g). The content of riboflavin in fish varies from 0.04 mg in 100 g to 0.3 mg in 100 g. Among red meats, beef is distinguished by its high content of vit B_{12} that varies from 0.6 to 7 μg/100 g of the raw product. Beef is also a good source of other B vitamins like, among others, vitamin B6 (0.5 – 0.8 mg/100 g) and niacin (5.7 – 6.9 mg/100 g) [5–7].

Thiamine diphosphate is a biologically active co-enzymatic form of vitamin B_1 . It holds three fundamental functions on the body, such as: it takes part in energy processes, in reactions of the pentose pathway that lead to the formation of ribose essential in the synthesis of nucleotides and NADPH, as well as in neurophysiological processes. Furthermore, it is a co-enzyme of numerous enzymes, mostly decarboxylase of alpha keto acids and transcetolase, both of which take part in the indirect carbohydrates transformation. Thiamine triphosphate holds an important function in the transmission of nerve impulses. Similarly to other water-soluble vitamins, thiamine is not accumulated in significant amounts, therefore, constant replenishment is crucial. Diet devoid of thiamine can lead to the depletion of the body reserves in 2 weeks time or even faster. The highest amounts of thiamine are accumulated in the heart, kidneys, liver and the brain. Blood contains only about 0.8% of the whole amount of thiamine in the body [4,7].

The requirement for thiamine was established in the 1940s. It was determined then that there was a strict correlation between the need for this vitamin and the amount of supplied energy. The studies established that the symptoms of clinical deficiency subsided after the intake of 0.2 – 0.4 mg of thiamine per 1000 kcal. The correct content of transketolase in the erythrocytes was achieved after the intake of 0.5 mg up to 0.6 – 0.8 mg/1000 kcal.

The aim of this study was to assess the B vitamins content in various culinary elements of raw and thermal processed beef with differing maturity degree.

Material and methods

Three culinary elements have been studied: tenderloin, rump cut and silverside. Each analysis was repeated 3 times. Altogether, each result constituted an average of at least 18 analytical determinations.

Studied culinary elements – samples were collected 24 hours after the slaughter, vacuum packed and refrigerated at 1°C for 5, 10 and 15 days. After the specified maturity time was achieved, the samples were frozen at -28°C and stored until chemical analyses were performed.

Thermal processing conditions: frying was performed at 180°C±5°C with an addition of a minimal amount of refined rapeseed oil (on the surface of the heating element); grilling – an electric grill with 180°C surface temperature was used; roasting – convection oven was used. In the case of each thermal process, it was continued until the temperature of 70°C was reached in the geometric centre of each portion of meat.

Vitamin content determination – meat samples of 5 g with the precision of 0.0001 g were weighed. The samples were mixed with hydrochloric acid solution and were homogenized until a homogeneous solution was achieved. Then, they were treated with a temperature of 121°C for 20 min in an autoclave. Takadiastase enzyme was added and they were incubated at 45°C. After the incubation, TCA solution was added, then, they were cooled, stirred and filled with distilled water to achieve necessary volume. The samples were centrifuged at 18000 rpm and 5°C. Supernatant was decanted through a syringe filter and the filtrate was placed in a vial up to 1.5 – 2 ml. Prepared samples were then separated chromatografically (LC/MS Agilent Technologies 6460 Triple Quad LC/MS with mass detector). Chromatographic separation was performed on C18 column. Phase A water with 0.05% TFA. Phase B acetonitrile.

Statistical analysis of the results was performed with the use of Statgraphics Centurion 15.2.11.0 computer program. It calculated average values, standard deviations as well as performed variance analysis, group homogeneity test, with the assumed statistical significance p=0.05.

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Results and discussion

Fig. 1 shows the comparison between the content of vitamin B_{12} and niacin (vit PP), and Fig. 2 the content of thiamine (vit B_1), riboflavin (vit B_2) and vit B_6 in five culinary elements of raw beef. The content of vit B_{12} varied from 1.5 to 3.4 μg/100 g, and niacin (vit PP) from 3.1 to 5.5 μg/100 g. The lowest content of these vitamins could be observed in the topside spread and the shoulder, however, tenderloin, silverside and rump cut contained a comparable amount and, at the same time, significantly higher than the topside spread and the shoulder (p=0032).

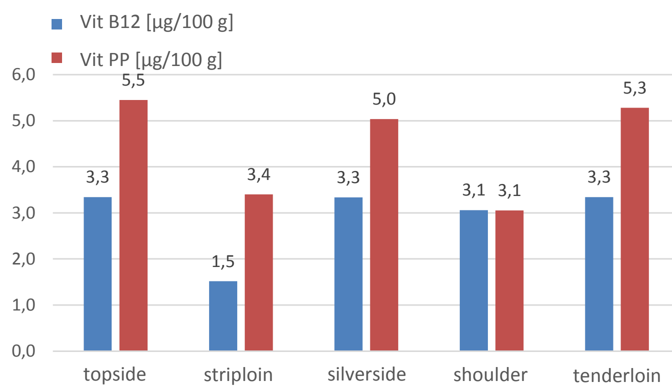

Fig. 1: The comparison between the content of vitamin B_{12} and niacin (vit PP) in various culinary elements of raw beef.

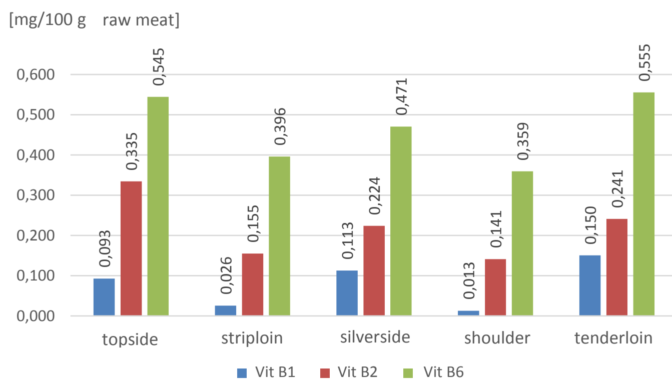

Fig. 2: The comparison between the content of thiamine (vit B_1), riboflavin (vit B_2) and vit B_6 in various culinary elements of raw beef.

After comparing the content of thiamine (vit B_1), riboflavin (vit B_2) and vit B_6 in various culinary elements of beef, it has been established that also their content depended significantly on the type of the culinary element. Similarly to vit B_{12}, the lowest content of thiamine (0.013 mg/100 g) could be seen in the shoulder, followed by the topside spread (0.026 mg/100 g), whereas, the highest content was in tenderloin (0.150 mg/100 g).

The influence of curing time on the content of thiamine (vit B_1) in beef

Table 1 depicts the content of thiamine in the studied culinary elements of beef (g/100 g of raw meet) that were cured for different periods of time, i.e. 5, 10 and 15 days.

During the curing time, various biochemical processes occur that affect not only the sensory quality and physical parameters (tenderness, hardness, succulence) of meat,

Table 1: The content of thiamine in various culinary elements of raw beef with different degree of maturity.

Curing time [days]	Thiamine content [mg/100 g of raw meat]	
	Tenderloin (n=54)	Rump cut (n=54)
5	0,126 ± 0,013	0,084 ± 0,008
10	0,120 ± 0,043	0,074 ± 0,025
15	0,117 ± 0,031	0,078 ± 0,020

but also shape the nutritional value of beef, including the content of vitamins.

Table 2: The average content of thiamine in various culinary elements of beef (average, minimum and maximum values).

Culinary Element Type	Tenderloin	Rump Cut	Silverside	(p)
Number of Repetitions (n)	54	54	54	
Thiamine (wit. B_1) [mg/100 g of raw meat]	0,121[a] (0,116-0,126)	0,079[b] (0,074-0,084)	0,106[c] (0,100-0,111)	0,0001

(a-c) – average values with different superscript differ statistically significantly from each other (ANOVA, p=0,05)

In order to establish the influence of the curing time of beef on the content of B vitamins, an experiment was conducted on three chosen culinary elements of beef that studied the changes in the content of thiamine (vit B_1). Beef could be characterised by a relatively low content of thiamine, between 0.074 to 0.126 mg in 100 g of meat, and its content depended only on the type of the culinary element of beef (p=0.0001, Table 2), and not on the curing time (p=0.105) – Table 3.

Table 3: The average content of thiamine in beef with different degree of maturity (average, minimum and maximum values).

Curing Time (days)	5	10	15	Statistical Significance (p)
Number of Repetitions (n)	54	54	54	
Thiamine (vit B_1) [mg/100 g of raw meat]	0,108[a] (0,100-0,114)	0,098[a] (0,091-0,105)	0,100[a] (0,093 – 0,107)	0, 105

a – no significant differences between compared average values (ANOVA, p=0,05).

The influence of thermal processing on the content of thiamine (vit B_1) in beef

In order to establish the influence of thermal processing of beef on the behaviour of thiamine (vit B_1), the processes of frying and grilling of two culinary elements, tenderloin and rump cut, as well as roasting of silverside were performed.

Frying

Table 4 depicts the content of thiamine in different culinary elements of beef that were cured for different periods of time before the process of frying was performed.

Table 4: The content of thiamine in different culinary elements of fried beef that were refrigerated for different periods of time before the process of frying was performed.

Curing Time [days]	Thiamine Content [mg/100 g of fried meat]	
	Tenderloin (n=54)	Rump Cut (n=54)
5	0,077 ± 0,008	0,067 ± 0,007
15	0,072 ± 0,018	0,061 ± 0,016
10	0,070 ± 0,023	0,060 ± 0,020

The content of thiamine in fried meat varied from 0.06 to 0.077 mg/100 g of meat and differed significantly in both compared culinary elements (p=0.0011). Irrespective of the degree of maturity of meat before frying (5, 10 or 15 days), fried tenderloin contained significantly more thiamine (0.073 mg/100 g) than fried rump cut (0.062 mg/100 g of meat) – Table 5.

Table 5: The average content of thiamine in chosen culinary elements of fried beef (average, minimum and maximum values).

Culinary Element Type	Tenderloin	Rump Cut	Statistical significance (p)
Number of Repetitions (n)	54	54	
Thiamine (vit B_1) [mg/100 g of raw meat]	0,073[a] (0,069-0,078)	0,062[b] (0,058-0,067)	0,0011

(a-b) – average values with different superscript differ statistically significantly from each other (ANOVA, p=0,05).

Despite slight tendencies towards lower content of vit B_1 in fried meat that was cured for a longer period of time (Table 4), observed differences were not statistically significant (p=0.164) – Table 6.

Table 6: The average content of thiamine in fried beef with different degree of maturity (average, minimum and maximum values).

Curing Time (days)	5	10	15	Statistical Significance (p)
Number of Repetitions (n)	36	36	36	
Thamine (vit B_1) [mg/100 g of raw meat]	0,072[a] (0,066-0,077)	0,067[a] (0,061 – 0,072)	0,065[a] (0,059-0,070)	0, 164

a – no significant differences between compared average values (ANOVA, p=0,05).

Grilling

Table 7 presents the content of thiamine (vit B_1) in two culinary elements of beef that were cured for different periods of time before thermal processing (grilling) was performed.

Grilled meat contained from 0.045 to 0.075 mg thiamine. It has been established that 100 g of tenderloin contains almost twice as much thiamine (p=0.0001) than grilled rump

Table 7: The average content of thiamine in different culinary elements of grilled beef with different degree of maturity.

Curing Time [days]	Thiamine Content [g/100 g of raw meat]	
	Tenderloin (n=54)	Rump Cut (n=54)
5	0,075 ± 0,008	0,053 ± 0,006
10	0,067 ± 0,023	0,045 ± 0,016
15	0,069 ± 0,018	0,048 ± 0,013

cut (Table 8). Similarly to frying, a slightly lower content of thiamine could be observed in grilled meat with longer curing time, however, the differences were not significant (p=0.104) – Table 9.

Table 8: The average content of thiamine in chosen culinary elements of grilled beef (average, minimum and maximum values).

Culinary Element Type	Tenderloin	Rump Cut	Statistical Significance (p)
Number of Repetitions (n)	54	54	
Thiamine (wit. B_1) [mg/100 g of raw meat]	0,070[a] (0,066-0,074)	0,049[b] (0,044-0,053)	0,0001

(a-b) – average values with different superscript differ statistically significantly from each other (ANOVA, p=0,05).

Table 9: The average content of thiamine in grilled beef with different degree of maturity (average, minimum and maximum values).

Curing Time (days)	5	15	10	Statistical Significance (p)
Number of Repetitions (n)	36	36	36	
Thiamine (wit. B_1) [mg/100 g of raw meat]	0,064[a] (0,059-0,069)	0,058[a] (0,053-0,063)	0,056[a] (0,051-0,061)	0, 104

a – no significant differences between compared average values (ANOVA, p=0,05).

Roasting

The element that underwent the process of roasting was the silverside. According to the results from preliminary examination, it was not viable for frying or grilling as it lacked tenderness and was hard, qualities that did not receive sensory acceptance. The process of roasting, however, appeared to be appropriate as it resulted in a product with adequate sensory qualities and ready for consumption. The average content of thiamine in roasted silverside varied from 0.083 to 0.095 mg/100 g of meat (Table 10).

The tendency for lowering the content of thiamine in raw meat with the duration of curing time was reflected in a similar tendency for roasted meat. However, the decreasing values following the increasing curing time did not differ significantly (p=0.229) – Table 11.

It has been established that 100 g of silverside contains on average 0.091 mg thiamine irrespective of the curing time before the thermal processing was performed (Table 12).

Table 10: The content of thiamine in roasted silverside with different degree of maturity.

Curing Time [days]	Thiamine content [mg/100 g of raw meat] (n = 108)
5	0,095 ± 0,014
15	0,083 ± 0,029
10	0,080 ± 0,040

Table 11: The average content of thiamine in roasted beef (silverside) with different degree of maturity (average, minimum and maximum values).

Curing Time (days)	5	15	10	Statistical Singnificance (p)
Number of Repetitions(n)	36	36	36	
Thiamine (vit B_1) [mg/100 g of raw meat]	0,096[a] (0,091-0,101)	0,089[a] (0,084-0,094)	0,087[a] (0,082-0,092)	0, 229

a – no significant differences between compared average values (ANOVA, p=0,05).

Table 12: The average content of thiamine in silverside after roasting (average, minimum and maximum values).

Culinary Element Type	Silverside
Number of Repetitions (n)	36
Thiamine (vit B_1) [mg/100 g of raw meat]	0,0910 (0,082-0,101)

Fig. 3 depicts the content of thiamine (vit B_1) in thermally processed meat (grilled, fried, roasted) compared to the content of thiamine in raw meat.

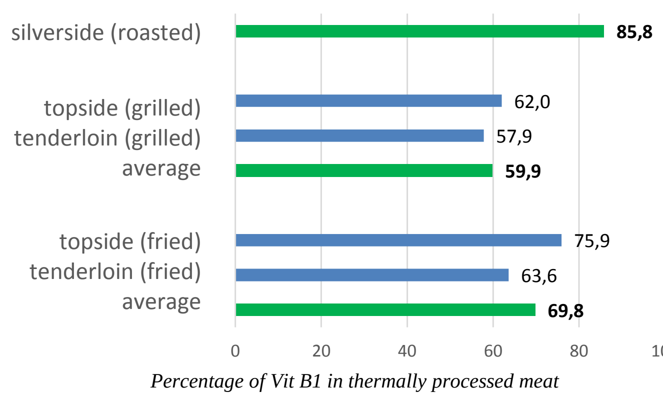

Fig. 3: The content of thiamine (vit B_1) in thermally processed meat (grilled, fried, roasted) compared to the content of thiamine in raw meat.

Thermal processing of beef resulted in significant varying decrease in the content of thiamine (vit B_1). After frying, 100 g of beef contained about 70% of the vitamin originally contained in raw meat; after grilling – around 60%, whereas, the highest content of the vitamin was present after roasting (85.5%), which was demonstrated with silverside.

Results discussion

The differences in the content of vitamin B_1 in various culinary elements depend on the chemical composition of meat [8,9]. Vitamin B_1 is water soluble, thus its higher content in lean rather than fat meat. In lean meat, the varying content of thiamine is related to the muscle structure – the content of connective tissue. The more fibrous or hard meat with high amount of connective tissue, the lower the content of vitamin B_1. It results from the specific role of this vitamin, which takes an active part in different biochemical processes in the muscles of the studied culinary elements. This explains why the highest content of thiamine is in tenderloin and then silverside, and the lowest in the rump cut, which is is a medium lean meat, and, therefore, contains significantly less water than tenderloin and silverside, and, ultimately, contains a statistically lowest amount of thiamine.

In the case of the curing process of these culinary elements, no significant differences in the content of thiamine have been found [9,10]. Vitamin B_1 is a vitamin connected with enzymatic proteins as it functions as a co-enzyme and takes part in different metabolic pathways. As a result, it is somewhat protected from the influence of oxygen, radicals and, therefore, it does not break down fast. Vitamin losses ought to appear in the presence of protein hydrolysis when thiamine is released in the form of e.g. phosphate that is characterised by low chemical resistance to oxidizing agents, temperature and can react with other meat ingredients, which, in result, can lead to high losses of thiamine. The curing process of meat is conducted at $0 - 1°C$. Low temperature impedes chemical and biochemical processes in meat and, in result, does not affect the content of the vitamin during the curing time of 15 days. Obviously, biochemical changes – the activity of proteolytic enzymes causes protein breakdown – hydrolysis that can result in thiamine breakdown, however, in this study, the effect of meat storage on the content of thiamine has not been clearly identified.

The content of thiamine in the studied culinary elements depends heavily on the type of thermal processing [11,12]. It has been established that the process of frying, grilling and roasting contribute to significant losses of the vitamin. The lowest breakdown of the vitamin can be observed during the roasting process, then frying and the highest losses are achieved during the grilling process. It is presumably due to the fact that meat undergoing the roasting process is usually in a one large piece and high temperature in the oven affects the content of the vitamin mostly on the outside part of the piece.

Since the temperature inside never exceeds 70°C, the loss of the vitamin is relatively low, and the surface to volume ratio is small compared to fried and grilled meat, in which the losses are much higher. In the case of grilling and frying, the losses of the vitamin are statistically identical, which results from the fact that the same temperatures were used and the time to achieve 70°C in both types of thermal processing was practically the same.

Conclusions

1. Beef is a good source of vitamin B_{12} and a poor source of other B vitamins, i.e. thiamine (vit B_1) or riboflavin. Different culinary elements of raw beef contain: vit B_{12} between 1.5 – 3.4 μg/100 g, niacin (vit PP) from 3.1 do 5.5 μg/100 g, and thiamine from 0.074 do 0.126 mg/100 g of raw meat.
2. The content of B vitamins in beef significantly depends on the culinary element type. Whereas, the curing time does not have a significant impact on their content.
3. Thermal processing significantly reduces the content of thiamine in beef, with grilling resulting in higher losses of about 40%, frying 30% and roasting of about 14%.

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