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BEEF AS A SOURCE OF BIOACTIVE COMPONENTS

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Summary. Beef is classified as the most valuable meat in terms of nutritional value. It contains a number of valuable bioactive substances, preferably affecting the functioning of the body. It is a rich source of protein, amino acids, bioactive peptides (including taurine, carnosine, creatine, carnitine) and contains collagen rich with hydroxy acids (hydroxyproline and hudroksylizyne). Beef is also characterized with a high content of B vitamins (especially B_{12} vitamin), minerals including most of all easily digestible iron, zinc and copper. Moreover, from a nutritional point of view beef fat contains lots of valuable components, such as conjugated linoleic acid (CLA), significant amounts of fatty acids from n-3 group and coenzyme Q_{10}. In comparison with meat obtained from other animals beef derived from animal meat breed is characterized by a low content of intramuscular fat (2–3%) which is connected with low content of saturated fatty acids. At the same time according to the latest data consuming too much red meat can pose a risk to health due to the development of many diseases.

Key words: beef, nutritional value, bioactive components

INTRODUCTION

Till now beef was regarded as a product of low health value due to the presence of saturated fatty acids that are responsible of cholesterol increase in the body. In recent years these views have changed dramatically, which is associated with a broad introduction to the market meat with a very low content of intramuscular fat (2–3%) that is derived from animal meat breed. Recently a lot of attention is paid to the other components of meat – valuable from nutrition point of view and beef is a rich source of these compounds. Quantities and relative proportions of bioactive compounds in meat depend on the animal

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species, age, sex, fattening degree, the type of fodder and the parts of the body, from which the meat comes from. Except of high quality protein content with favorable amino acid profile, beef is particularly rich in bioactive compounds, such as: taurine, carnosine, creatine, coenzyme Q_{10} and creatine [Purchas et al. 2004]. It contains far less appreciated collagen rich in hydroxy acids, recommended especially for convalescents for the regeneration of cartilage, joints, tendons, and people exposed to heavy joint loads, especially for athletes. Beef is a high source of B vitamins, especially B_{12} and minerals, such as iron, zinc and copper. In addition to the above-mentioned bioactive compounds beef is also a valuable source of conjugated dienes of linoleic acid (CLA), which in the human body have many healthy properties such as; prevention of atherosclerosis development, inhibit the development of osteoporosis, and fatty acids from n-3 group as well as coenzyme Q_{10} [O'Shea et al. 2005, Decker and Park 2010].

At the same time according to the latest data consuming too much red meat can pose a risk to health due to the development of many diseases such as the cardiovascular system diseases and the occurrence of cancer and gout [Gąsiorowska et al. 2008]. An important aspect tackled in terms of health safety of red meat consumption, including beef, should be the control of the content of technological contamination formed during heat processing, i.e. compounds which adversely affect human health.

The purpose of this article was to present the nutritional and health-related value of beef with particular emphasis on the content and significance of bioactive components such as collagen, B vitamins, minerals, conjugated linoleic acid (CLA), n-3 fatty acid, taurine, carnosine, L-carnitine, creatine and coenzyme Q_{10}. The article also highlights the negative impact of excessive consumption of red meat.

PROTEIN

Beef is an excellent source of high quality protein which is characterized by high absorption of approximately 94% (in comparison: beans – 78%, wheat – 86%). 100 g of this meat provides approximately 20 g of protein. Beef is a rich source of essential amino acids (lysine, threonine, methionine, phenylalanine, tryptophan, leucine, isoleucine, valine), which the human body is unable to produce. These amino acids must be supplied together with the diet in order to ensure proper health. Protein present in the meat is a rich source of glutamic acid and glutamine, whose content reaches 16.5% of protein, furthermore it also provides large quantities of arginine, alanine and aspartic acid. Meat proteins present in the animal body depending on their function differ in their amino acid composition and physicochemical features [Williams 2007, Hryniewiecki and Roszkowski 2008].

Collagen is the main compound of mammals connective tissue and represents about 30% of all proteins present in the human body. This compound has a large impact on the sensory quality and nutritional value of meat and its products. Collagen as the main component of connective tissue affects the tenderness of meat, which is one of the most important attribute of beef. In skeletal muscles of adult cattle collagen content ranges from 1 to 10% of total protein. Collagen is a special protein, which is rich in glycine (33% of the total collagen content), proline (10% of the total collagen content) and 4-hydroxyproline (14% of the total collagen content). Collagen does not contain tryptophan. The

content of sulfur aminoacids in collagen is very low. Also, the digestibility of collagen is smaller as compared to other proteins. Quantitative amino acid composition of collagen is not constant. It depends on the type of tissue and animal species, age, race and gender as well as intravital factors [Lepetit 2008, Żelaszczyk et al. 2012].

VITAMINS AND MINERALS

Meat has a high concentration of B vitamins and minerals. Among the meat species consumed by human, beef stands out higher content of vitamin B_{12}, and minerals such as iron, zinc and copper (Table 1).

Table 1. The content of vitamins and minerals per 100 g meat [Kunachowicz et al. 2005]

Tabela 1. Zawartość witamin i związków mineralnych w 100 g mięsa [Kunachowicz i in. 2005]

Component Składnik	Beef Wołowina	Pork Wieprzowina	Mutton Baranina	Poultry Drób
B_2 [mg]	0,26	0,24	0,19	0,15
B_{12} [μg]	1,4	0,7	1,0	0,4
Fe [mg]	3,1	0,9	2,7	0,4
Cu [mg]	0,1	0,02	0,06	0,01
Zn [mg]	2,93	1,88	3,2	0,49

Mineral content of beef varies due to the breed, age, muscle type, animal diet, geographical location and methods of farming and raw material processing conditions. Beef is a rich source of iron, zinc and copper. Iron is present in food in two forms: heme and nonheme. Heme form of iron occurs in meat and animal products. It is distinguished by higher absorbability (15–25%) than non-hem form (1–7%). The increase of heme iron absorbability is influenced by the presence of protein in meat [Higgs 2000, Crabera et al. 2010]. Iron is needed to carry oxygen in the body and is a component of enzymes involved in cellular metabolism and the body's immune response and plays a particularly important role in proper pregnancy [Brzozowska 2012]. Meat is an excellent source of B vitamins, it provides particularly B_1, B_2, B_6, B_{12} and PP vitamins. In the case of the above mentioned vitamins beef is an important source of these ingredients in daily diet, but pork contains more than five times more B_1 vitamin, almost twice more B_6 vitamin and a bit more vitamin B_2. However beef has the highest content of B_{12} vitamin compared with pork, chicken or lamb. It contains twice more than pork, and over three times more than poultry [Higgs 2000].

FAT AND FATTY ACIDS

In the 80s of the last century, red meat because of high fat content was seen as the main factor increasing the risk of heart disease. Taking this into consideration meat producers started developing a new animal breeding techniques in order to reduce fat content

in meat obtained from these animals. Due to the meat industry efforts they successfully reduced more than 30% fat content in pork, 15% fat in beef and 10% fat in mutton. In subsequent years there were further decreases in fat content by 5–10% related to beef and mutton. This conversion was achieved by appropriate selection of animals breeds for slaughter [Higgs 2002]. Beef intramuscular fat contains 45–48% SFA (saturated fatty acids), 35–45% MUFA (monounsaturated fatty acids) and about 5% PUFA (polyunsaturated fatty acids) [De Smet et al. 2004]. According to Kołczak [2008] in recent years, as a result of applied technology, it was succeeded in obtaining fat containing lower proportions of SFA and higher proportion of MUFA in beef meat. These changes are associated with an increasing of meatness in carcass.

The animal muscles with low intramuscular fat content (< 1%) have very high PUFA/SFA ratio with amounts from 0.5 to 0.7. This is due to the growth of the total PUFA content, which is associated with a neutral lipid reduction and an increase of phospholipids in fat. Beside that the PUFA content in beef is still considered to be at low level.

Beef is an excellent source of conjugated diene linoleic acid (CLA), which have a number of beneficial effects on the body. CLA are composed of the position and geometric isomers of linoleic acid (C18:2). In beef and dairy products the c9, t11-18:2 isomer (rumenic acid) is dominant (approximately 80% of total CLA). Meat obtained from poligastric animals has a much higher content of CLA compared to monogastric animals. The main sources of CLA in the human diet is meat and dairy ruminants (Table 2).

Table 2. The content of CLA in food products [mg·g fat^{-1}] [Rainer et al. 2004]

Tabela 2. Zawartość CLA w produktach żywnościowych [mg·g fat^{-1}] [Rainer i in. 2004]

Product Produkt	Beef Wołowina	Pork Wieprzowina	Poultry Drób	Mutton Baranina	Sunflower oil Olej słonecznikowy	Salmon Łosoś
CLA content Zawartość CLA	4,3	0,6	0,9	5,8	0,4	0,3

The fat in beef contains significant amounts of CLA which have health benefits, mainly due to two isomers: c9, t10 and 11t, 12c. CLA affects the inhibition of cancer development in particular breast, lung, gastrointestinal, ovarian, melanoma and leukemia. It has also been shown that CLA protects against cardiovascular disease – vascular, contribute to weight loss, affects normal bone mass. It exhibits antioxidant and anti-atherosclerotic properties, stimulates the immune system and prevents and relieves the symptoms of type 2 diabetes mellitus [De La Torre et al. 2006].

OTHER BIOACTIVE COMPOUNDS

Meat is not only an excellent source of complete protein and easily digestible forms of vitamins and minerals, but also contains a number of substances that exhibit biological activity and have a positive impact on the functioning of the body. These compounds include taurine, carnosine, coenzyme Q10, creatine and L-carnitine. The contents of the

Table 3. The content of the various bioactive components in selected muscles and organs of cattle [mg·100 g^{-1}] [Purchas 2004, Purchas and Busboom 2005]

Tabela 3. Zawartość różnych składników bioaktywnych w wybranych mięśniach i narządach wołowych [mg·100 g^{-1}] [Purchas 2004, Purchas i Busboom 2005]

Type of muscles/ograns Rodzaj mięśni/narządów	Taurine Tauryna	Carnosine Karnozyna	Coenzyme Q_{10} Koenzym Q_{10}	Creatine Kreatyna	Creatinine Kreatynina
M. Longissimus dorsi	51,0	432,6	1,44	383,0	–
M. Triceps brachii	103,4	299,1	2,88	329,0	–
M. Semitendinosus	38,6	452,6	2,18	401,0	5,82
Heart – Serce	22,3	32,6	6,05	298,0	2,16
Liver – Wątroba	45,8	77,5	4,6	16,0	0,54

various bioactive components are shown in Table 3 [Purchas et al. 2004, Purchas and Busboom 2005].

Taurine (2-aminoethanesulfonic acid) is a nonprotein amino sulfuric acid, which is found widely in mammalian tissues, where it reaches the highest concentration in skeletal muscle, heart, brain and retina. In muscle taurine is present in free form. Taurine sweeps free radicals. In the human body acts as a neurotransmitter and neuromodulator, also by interaction of the ion channels can regulate the concentration of calcium ions and hold calcium homeostasis. In addition, taurine is involved in the formation of bile acids, and in body osmoregulation. Currently, taurine is a common additive to energy drinks, supplements for elderly people and to children's porridges [Wang et al. 2009, Djenane et al. 2002, Szymański and Winiarska 2008].

Carnosine (Nb-alanyl-L-histidine) is an endogenous dipeptide and the main nonprotein nitrogen-containing compound in the skeletal muscles of vertebrates. It occurs in white muscle fibers, in which the accumulation of lactic acid is increased. This white muscle fibers appear in central nervous system of mammals, particularly in olfactory neurons and glial cells [Zięba 2007].

The content of carnosine closely relates to applied diet, because diet low in histidine leads to a reduction in the concentration of carnosine in muscles, and increased supply of this amino acid in diet plus an additional supplementation leads to increase the presence of carnosine in muscles. Carnosine is about 0.2–0.5% of striated muscle weight and its content decreases with age. This dipeptide has a strong antioxidant features, is able to inactivate peroxyl and hydroxyl radicals, singlet oxygen and chloramine. Carnosine shows the buffering effect and helps maintain the acid-base balance in the muscle at the appropriate level. It has the ability to chelate metal ions thereby affect their concentration while decreasing their toxicity. In addition to that carnosine inhibits lipid peroxidation [Purchas et al. 2004, Das et al. 2006, Badr 2007].

Coenzyme Q_{10} (2,3-dimethoxy-5-methyl-6-dekaprenyl-1,4-benzoquinone), otherwise known as ubiquinone or Q_{10} vitamin is involved in the mitochondrial electron transport in the respiratory chain and ATP particles production. It occurs in all cells, improving mitochondrial activity, in particular in the cells requiring large amounts of energy such as heart cells. Its content in meat is correlated with the amount of mitochondria in the muscle. Coenzyme Q_{10} also helps to regenerate other important lipophilic antioxidant

which is α-tocopherol. Ubiquinone in largest quantities is present in beef, chicken and broccoli, less content is in soybean oil, fish oil, peanuts, sardines and mackerel [Siemieniuk and Skrzydlewska 2005, Shults 2005, Pepe et al. 2007, Miller et al. 2007, Kumar et al. 2009].

L-carnitine (β-hydroxy-gamma-trójmetyloaminomaślan) is a derivative of lysine and a component of mammalian tissues. It is synthesised endogenously in the body, primarily in the kidneys, liver and brain, and is supplied to the body with food. It is believed that with the diet about 80% of the total content of L-carnitine is provided to the body. The main function of L-carnitine is to facilitate the active transport of long-chain fatty acids from the cytosol to the mitochondria, where it then takes part in the process of β-oxidation and energy production. Too low concentration of this compound may lead to decrease fatty acid oxidation, neurological disorders, muscular weakness, especially heart ones. In these physiological conditions and during pregnancy L-carnitine should be supplied to the body in an increased dose. The main source of this compound in the diet is red meat, fish and dairy products [Knüttel-Gustavsen and Harmeyer 2007, Rigault et al. 2008].

Creatine is produced by the biosynthesis of arginine, glycine, and methionine in the liver, pancreas and kidney. It is located in skeletal muscle tissue, in the heart and central nervous system. Creatine plays a key role in energy metabolism in skeletal muscle, to provide the necessary quantity in order to have the intense muscle contractions. Especially in tissues having a high energy transfer to ADP in muscle cells. This compound may be supplied by the diet. Abundant amount of creatine is in meat and fish. In the body, it is slowly converted to creatinine by the removal of water and formation of a ring structure, and then passes into the blood and is excreted in the urine [Purchase 2004, Mora et al. 2008, Mora et al. 2010].

RISK ARISING FROM EXCESSIVE CONSUMPTION OF BEEF MEAT

According to the data presented above beef can be a good source of many important bioactive compounds in the diet. At the same time according to the latest data consuming too much red meat can pose a risk to health due to the development of many diseases. This is especially connected with the appearance of atherosclerotic lesions as a result of the accumulation of homocysteine in the body and the development of gout as a result of abnormal changes of purine compounds. Homocysteine has been named as "the cholesterol of twenty-first century". There is increasing evidence that the common cause of development of the cardiovascular system diseases and the occurrence of cancer (colon, breast, prostate) is homocysteine – a little known amino acid formed in the digestion of animal protein contained mainly in red meat. This compound in the deficiency of B vitamins reduces the elasticity of blood vessel walls and causes regular deposition of atheromatous plaques in the veins and arteries. In patients with high concentrations of this amino acid appears to be almost twice the mortality due to diseases of the cardiovascular system and cancer [Wieczorek et al. 2004, Sawicki et al. 2007, Gąsiorowska et al. 2008]. Another disease connected with excessive consumption of meat dishes is the development of gout. In recent years there has been a more and more cases of this disease. This

is particularly true of highly developed countries. Gout is a disease that occurs due to the abnormal metabolism of purine compounds, which are present in large quantities in red meat and seafood. The result of abnormal metabolism of purine compounds is abnormal increase in the level of uric acid and urate deposition, often accompanied by painful arthritis [Majdan and Borys 2010].

An important aspect tackled in terms of health safety of red meat consumption, including beef, should be the control of the content of technological contamination formed during heat processing, i.e. compounds which adversely affect human health. The precursors of these compounds may be some bioactive components discussed above, such as free amino acids (favoring the formation of heterocyclic aromatic amines – HAA) or fatty acids, especially unsaturated, n-3 fatty acids (polycyclic aromatic hydrocarbons precursors – PAHs). HAA and PAHs compounds are potentially carcinogenic. Their formation is largely dependent on the treatment temperature (above 150°C), its type (smoking, grilling, frying or grilling) and time [Ahn and Grün 2005, Jasna et al. 2008, Oz et al. 2010].

CONCLUSIONS

Based on the literature data regarding the nutritional value of beef and its bioactive components it can be stated that:

1. Beef is a source of collagen which is characterized not only by valuable sensory features of meat but also it has an important role in weight control, as well as it affects the health of joints.
2. Beef is a valuable resource of B vitamins, especially vitamin B_{12} and minerals, such as iron, zinc and copper.
3. Beef meat has a low intramuscular fat content and thus a low content of saturated fatty acids such as palmitic and myristic acids, which have a positive effect on the increase of LDL cholesterol level in the blood.
4. Beef is a natural source of many bioactive compounds. It is a valuable source of CLA and n-3 fatty acids in the diet. These compounds have many healthy features in the human body, for example they prevent the development of atherosclerosis and inhibit the development of osteoporosis. Beef contain also such bioactive compound as: taurine, carnosine, L-carnitine, creatine, and coenzyme Q_{10}. These compounds perform a variety of functions in the body: eliminate free radicals, protect heart muscle against the occurrence of coronary heart disease, as well as they are involved in energy metabolism in skeletal muscle.
5. An important factor in the health safety of beef is a proper selection of the parameters of its heat treatment to reduce the amount of compounds that are potentially carcinogenic. It should be remembered that HAA precursors are formed from free amino acids (meat with a long aging time) and PAHs – unsaturated fatty acids.
6. It is important to proper balance the daily diet. On the one hand the usual intake of red meat should be a good opportunity to provide to the body many bioactive compounds, but on the other hand it should not contribute to the development of many diseases associated mainly with the excessive consumption of such meat.

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MIĘSO WOŁOWE JAKO ŹRÓDŁO SKŁADNIKÓW BIOAKTYWNYCH

Streszczenie. Mięso wołowe pod względem odżywczym zaliczane jest do najwartościowszych mięs. Mięso to jest źródłem wielu cennych substancji bioaktywnych, korzystnie oddziałujących na funkcjonowanie organizmu, bogatym źródłem pełnowartościowego białka, bioaktywnych aminokwasów i peptydów (m.in. tauryny, karnozyny, kreatyny, karnityny) oraz zawiera bogate w hydroksykwasy (hydroksyprolinę i hydroksylizynę) białka

kolagenowe. Mięso wołowe charakteryzuje się także wysoką zawartością witamin z grupy B (głównie witaminy B_{12}), składników mineralnych, w tym przede wszystkim łatwo przyswajalnego żelaza, cynku i miedzi. Ponadto tłuszcz wołowy zawiera wiele cennych, z żywieniowego punktu widzenia, komponentów, takich jak: sprzężony kwas linolowy (CLA), znaczne ilości kwasów tłuszczowych z rodziny n-3, czy koenzym Q_{10}. Mięso wołowe pochodzące od zwierząt ras mięsnych cechuje się niską zawartością tłuszczu śródmięśniowego (ok. 2–3%) i z tym związaną niską zawartością kwasów tłuszczowych nasyconych w porównaniu do mięsa pochodzącego od innych gatunków zwierząt. Jednocześnie według najnowszych danych spożywanie zbyt dużych ilości mięsa czerwonego może stwarzać zagrożenie dla zdrowia wskutek rozwoju wielu chorób.

Słowa kluczowe: mięso wołowe, wartość odżywcza, składniki bioaktywne mięsa