CURRENT CONCEPTS ON THE NUTRITIVE AND BIOLOGICAL VALUE OF MEAT RAW MATERIALS WITH A HIGH CONTENT OF CONNECTIVE TISSUE

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SUMMARY

Analysis of literature data and our own experimental results have proved the affinity of connective tissue elements from animal and vegetable dietary fibres in relation to their positive physiological effect on the human alimentary tract. The effect of collagen content on the biological value of meat proteins has been studied. It has been demonstrated that an increase in the collagen content to 15-20% of the total content of meat proteins leads to heightened total efficacy of using protein for tissue synthesis. Thus, the above level of collagen content in meat raw materials does not reduce but, conversely, enhances its nutritive and biological value and renders it more suited for the digestive processes in the human body.

ABSTRACT

It has been shown that an increase in the collagen content in meat raw materials to 15-20% of the total content of meat protein enhances their nutritive and biological value and makes them more suite for man's digestive processes.

INTRODUCTION

Collagen is the basic protein of the animal connective tissue. Making up over 30 per cent of the total content of the body's proteins collagen attracts great attention on the part of scholars and experts working in various branches of the industry. Problems resulting from determining the rational collagen content in meat products is an area of particular scrutiny. According to the conventional concepts, an increase in the specific weight of collagen in meat products lowers the absolute content of the product's essential amino acids and disturbs their mutual balance thus worsening the protein system's biological value. As a result, in estimating the quality of meat products use is made of the tryptophane/oxyprolyn index that reflects the correlation between muscle and connective tissue proteins. It is believed that the magnitude of this coefficient is directly proportional to the protein value of meat (4) . All this considered, a tendency has arisen in the meat industry to most fully remove connective tissue while treating meat raw materials. Yet, at the present time there are sufficient grounds for revising the conventional views on collagen in this respect.

The aim of the present paper is to revise, using literature data and our own results, the conventional views on collagen as a negative criterion of the quality of meat raw materials, and determine its rational content in meat products.

MATERIALS AND METHODS

While determining the amino acid composition of meat raw materials depending on the collagen content use was made of the accepted methods for computer simulation of multicomponental protein systems (3). Calculations were performed for a muscle protein collagen system using a computer. The amino acid composition of the initial protein ingredients has been borrowed from the works by Asghor et al. (1982). The effect of elastin was neglected since it is not virtually split by the enzymes of the gastrointestinal tract and, hence, makes no contribution to the total amino acid fund.

RESULTS AND DISCUSSION

The primary reason for revising the conventional views on collagen was preliminary information of foreign researchers who pointed out a certain affinity of the physiological effect produced by vegetable dietary fibres (DF) and animal connective tissue elements on the human alimentary tract (Sinclair, 8 ; Trowell, 9). Proceeding from this information we outlined a research programme and then scientifically interpreted the obtained results that proved the correctness of associating collagen and allied mucopolysaccharides with DFs (2) Experiments on dogs with isolated sections of the stomach and the small intestine as well as studies on growing rats have shown that: first, like DFs connective tissue proteins ensure the formation of gel-like structures which by far facilitates the emptying of the stomach. The structuralization of food influences the absorption rate in the small intestine and the transition period through the gastrointestinal tract; second, while passing through the acidic medium of the stomach collagen acquires the ability to retain a considerable amount of water which greatly influences the intraluminal pressure, the mass and electrolytic composition of the faeces. This also points to its affinity with dietary fibres. Both substances stimulate the functions of the digestive glands.

Experiments with radioactive isotopes have established that both DFs and non-assimilable connective tissue proteins are quite important for the electrolytic metabolism in the gastrointestinal tract. This is due to the fact that like vegetable polysaccharides collagen displays cation-metabolic properties and promotes the elimination of different metals. Also of importance is the fact that DFs and connective tissue elements are next to the main components constituting a habitat for useful intestinal bacteria. (5) Thus, analysis of the previously advanced assumptions, as well as our own experimental results prompt the conclusion that both substances are dietary components ensuring physiologically normal functioning of the digestive system engendered in the course of man's evolution. Therefore, a certain content of collagen in meat raw materials does not reduce but, conversely, heightens their nutritive value by rendering them more suited for assimilating food in the gastrointestinal tract.

It should, however, be emphasized that an increase in the DF content in meat products at the expense of connective tissue components has its specifics and limitations. First and foremost, it applies to the collagen effect on the biological value of the meat protein system. It is due to that role of dietary fibres is largely performed by non-assimilable connective tissue elements. The collagen bulk is split to amino acids and participates in the metabolic processes together with the hydrolysed products of other proteins. Thus, the connective tissue content in meat products may be increased only to a level that would not affect the biological value of

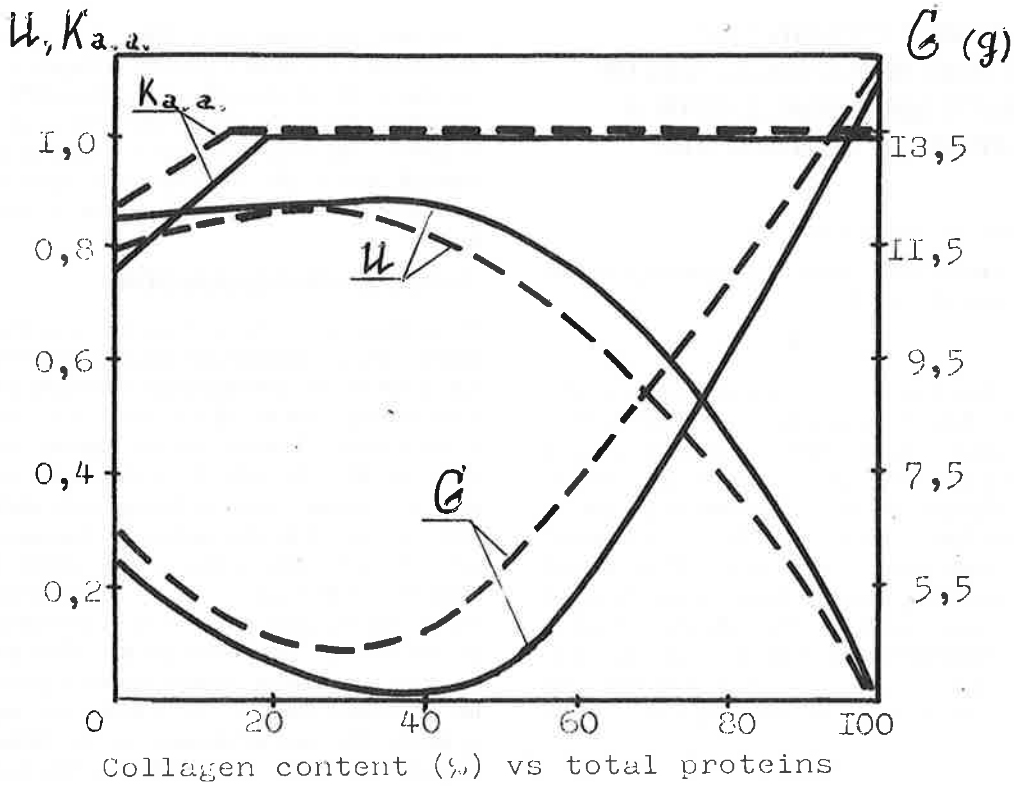

Figure 1. A dependence of coefficients of amino acid utility U, comparable excess G and the amino acid coefficient $K_{a.a.}$ on the collagen content: - - - beef; —— pork.

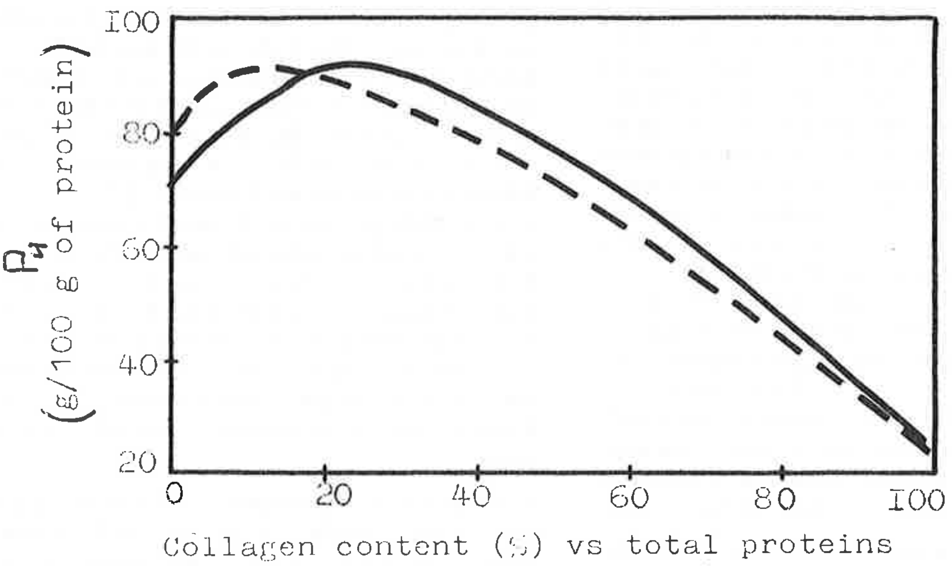

Figure 2. Effect of the collagen content on the quantity of utilized protein P_u per 100 g of consumed meat protein: - - - beef; —— pork.

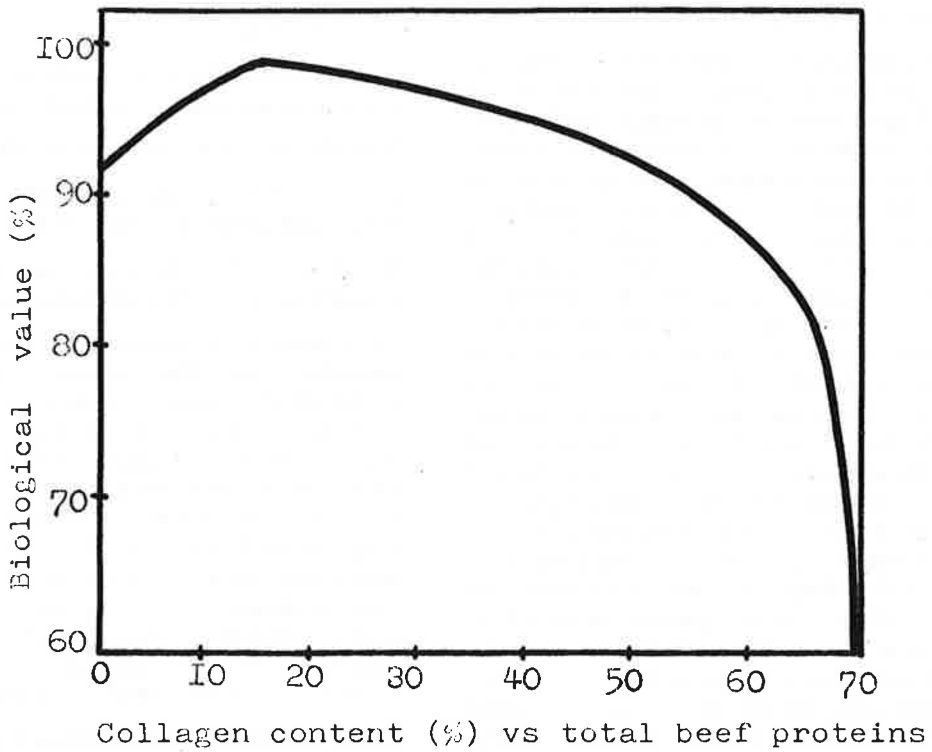

Figure 3. Effect of the collagen content on the biological value of beef proteins determined by the index of zero nitrogen balance in experiments with volunteers (according to Kofranyi et al., 1969).

Figure 4. Effect of the collagen content in beef on the quantity of utilized protein P_u from various meat dishes (collagen content % vs total meat proteins; 1 – 5%; 2 – 15%; 3 – 25%)

meat proteins. So, the goal of further studies was to determine a rational level of collagen content.

The experiments conducted have revealed that certain conventional views should be revised in the problem of collagen effect on the biological vlaue of meat products. The basis for this is the developing theory on a balanced nature of nutrients. First and foremost, it applies to the appearance of sufficiently reliable methods for determining qualitative indices of proteins depending on the complex of essential amino acids (3 , 6). To fully elucidate this phenomenon, let us make a few remarks that do not run counter to the conventional concepts on diet on the one hand, and allowing motivation of the conclusions differing from the current ones, on the other. The biological value of a product's protein system is known to be an integral parameter that primarily depends on the balance of the amino acid composition of the product per se but not on the balance of the amino acid composition of is constituent proteins. Proceeding from this, it may be assumed that although as the collagen content in the product grows the absolute content of essential amino acids will decrease. Yet, their balance with respect to the FAO/WHO reference protein will unlikely to display a strictly inverse proportional dependence. This assumption is based on the presence in muscle tissue proteins of a considerable amount of unbalanced essential amino acids in comparison with the reference sample. Apparently, in combination with connective tissue proteins poor in these amino acids the total balance will not worsen as long as the collagen content is elevated to definite limits.

For quantitative description of the above dependences let us use coefficients U and G proposed by Черников 6). The coefficient of utility U characterized the balance of essential amino acids (EAA) contained in the protein with respect to the FAO/WHO reference protein. Therefore, it reflects the part of EAAs that can be theoretically utilized by the body for plastic purposes. The coefficient of comparable excessiveness G is numerically equal to the total mass (EAAs) potentially non-utilized due to a disturbed balance with respect to the reference protein in such an amount of concrete protein that is equivalent to 100 g of the reference protein by the content of potentially utilized essential amino acids.

Another factor supporting the above assumption is the absence in muscle tissue proteins of the physiologically required correlation between the total masses of essential and non-essential amino acids. Let the correlation between the mass of non-essential amino acids (NEAA) and the mass of essential amino acids in the reference protein be C_r. In this correlation all EAAs will directly be utilized for tissue synthesis.

In the case of concrete protein the whole part of balanced essential amino acids can be utilized for plastic purposes once condition

C_p = NEAA: (U·EAA) $\geq C_r$ is fulfilled. If $C_p \leq C_r$ the actual value of the coefficient of EAA utilization for anabolic purposes will be less than U due to an excess of balanced EAAs with respect to NEAAs. Thus, the quantitative characteristic of a protein reflecting its part that can directly be utilized for tissue synthesis depending on the NEAA/EAA correlation may be the amino acid coefficient $K_{a.a.}$ calculated via formula

$$K_{a.a.} = \frac{NEAA}{U\,EAA} : C_r \quad (1)$$

where NEAA, EAA is the total mass of nonessential and essential amino acids, respectively, in g/100 g of protein.

Naturally, this coefficient must be considered only for

$K_{a.a.} < 1$. For $K_{a.a.} \geq 1$ this coefficient provokes no effect on protein utilization and is taken to be equal to unity.

The above coefficients were calculated and, hence, the assumptions verified for a muscle protein/collagen system.

The magnitudes of coefficients U, G and $K_{a.a.}$ for the system depending on the collagen content in the whole protein mass are presented in Figure I. Analysis of the charts shows that as the specific ratio of collagen increases to 30 per cent of the total proteins in beef and to 40-45 per cent in pork, the balance of essential amino acids grows vs the reference model (U) with a parallel decrease in their content potentially utilized by the body for catabolic purposes (G). A further increase in the connective tissue protein content leads to drastic reverse changes. The physiologically needed correlation between nonessential and essential amino acids ($K_{a.a.}$) also improves to achieve its optimum at 15-20 per cent of the collagen contained in the system.

The above indices vividly confirm the assumption about a relatively positive effect of a certain collagen content on the qualitative characteristics of a protein system. Yet, despite their informative nature these coefficients take into account but individual specifics of protein and, hence, cannot serve as a final criterion of quality. So, it has been proposed to use index P_u reflecting the amount of potentially utilized protein per 100 g of consumed protein. This magnitude can serve as an integral characteristic of the biological value of protein, and is calculated via equation

$$P_u = 100.K_{dig.}.(K_{a.a.}.C_{min} + K) \quad (2)$$

where $K_{dig.}$ is the coefficient of digestibility of a protein system by the enzymes of the gastrointenstinal tract; K is the coefficient of compensation reflecting the body's participation in correcting the disturbed protein balance at the expense of an excess fund of essential amino acids, as well as its internal reserves (6) C_{min} is the score of the limiting amino acid.

It has been established on the basis of the available data (Asghor et al., 1982) that the digestibility of connective tissue proteins varies within virtually the same range as that of muscle proteins, making up 85-95 per cent. The high accessibility of collagen to proteolytic enzymes is due to its denaturation changes resulting from mechanical and thermal treatment as well as the effect of the acidic medium of the stomach. In our case, $K_{dig.}$ was taken to be equal to 0.9. The coefficient of compensation was calculated from the condition that for purely muscle proteins K=O and for purely connective tissue ones K=0.25 (6).

If in equation (1) coefficient U considers the degree of balance of essential amino acids in the consumed protein and, hence, the efficacy of their utilization for plastic purposes. C_{min} in equation (2) considers the devgree of utilizing the whole protein for tissue synthesis since it reflects the level comparable with that of the reference sample, at which the best EAA balance is attained. By analogy with $K_{a.a.}$ the score of the limiting amino acid in equation (2) is considered only for $C_{min} < 1$. In all other cases it is taken to be equal to unity. Computer-assisted calculations of the dependence of utilized protein (P_u) content on the collagen content in the system are presented in Table 2. Analysis of the charts proves that an increase in the collagen content to 15% of beef and to 20% of pork leads to an increase in the total anabolytic "usefulness" of protein, and promotes rational utilization of essential and non-essential amino acids. An increase in the collagen content to 30-35% in beef and 40-45% in pork worsens these indices, although they are not lower than in the case of muscle proteins.

The data presented have allowed us to scientifically interpret the findings obtained by Kofranyi et al. (1969). Figure 3 shows the effect of adding collagen (gelatin) to beef muscle tissue on the biological value of the summary system of these proteins vs the biological value of chick embryo proteins taken as 100%. It proceeds both from those experiments and our own results that a mixture consisting of 84% of muscle protein and 16% of connective tissue proteins of beef exceeds the biological value of purely muscle tissue. Once 50% of muscle protein are replaced by connective tissue protein the biological value of the mixture proved equal to the analogous index for muscle tissue. Other researchers also point out a positive effect of a certain collagen content on the quality of meat proteins (1 ; 4).

Yet, there are literature data somewhat differing from the calculated ones (Asghor et al., 1982). Rat experiments indicate an inverse-proportional dependence of coefficients of efficacy and pure utilization of protein on the collagen content in beef proteins. Probably, one of the reasons for such incongruity are specific features of the rat organism requiring a balance of not 8 EAAs like in the case of humans, but 10. The experimental conditions are also an important factor. Yet, an unambiguous conclusion was made even on the basis of these results. An increase in the collagen content to 28-30% of the total beef proteins does not lower the coefficients of efficacy and pure utilization of protein by more than in the case of complete proteins. (2.5 g/g and 65%, respectively) which is, in principle, in good agreement with our data.

Since meat and meat products are usually consumed with such vegetable food-stuffs as bread, rice, potatoes, etc. we have estimated the quality of a summary mixture of these proteins. It has turned out that the regularities discovered for pure meat hold true for these protein mixtures. It follows from Fig. 4, in particular, that the completeness of protein mixtures with meat containing 15% of collagen is higher than for meat containing 5% of collagen. The correlation between meat and various vegetable products is taken with account of public catering norms. The preserved regularity is due to the fact that vegetable proteins are poor in sulphur-containing amino acids, lysine and treonine. At the same time, meat proetins, even when they contain 15-20% of collagen have a considerable excess of these amino acids.

Thus, proceeding from the new concepts on collagen as a physiologically useful ballast substance, and the new data pointing to its effect on the quality of meat products, it can be concluded that an increased collagen content in meat to 15-20% of the total protein mass enhances the nutritive and biological value of the meat, rendering it more suited for man's alimentary processes. It should, however, be pointed out that an increase in the collagen content shall not exceed 25-30% of the total meat proteins not only from the point of view of biological value, but in relation to a growing load on the kidneys (Asghor, et al., 1982). It is quite understandable that in the whole complex of the above measures the organoleptic properties of ready food stuffs should be given priority to.

REFERENCES

1. Н.Г.Беленький.Повышение качества продуктов животноводства.-М.,1978,с.10-39.
2. Ю.И.Ковалев,Э.С.Токаев,И.А.Рогов.О пищевой и биологической ценности мясного коллагенсодержащего сырья.-В сб.Всесоюзной конференции "Пури развития,производства и переработки животноводческого сырья в системе АПК",М.,1988
3. Н.Н.Липатов.Некоторые аспекты моделирования аминокислотной сбалансированности пищевых продуктов.-Пищевая и перерабатывающая промышленность,1986,№4,с.48-52.
4. Р.М.Салаватулина.Рациональное использование сырья в колбасном производстве.-М.:Агропромиздат,1985,256 с.
5. В.И.Смоляр.Эффекторы энергетического метаболизма.-Вопросы питания,1987,№ 5,с.16-21.
6. М.П.Черников.К вопросу о рациональной классификации пищевых белков.-Вопросы питания,1986,№ 5,с.68-70.
7. E.Kofranyi, F.Jekat. Zur Bestimmung der biologischen Wertigkeit von Nahrungsproteinen. - Z.Physiol.Chem., 1969, v. 350, p. 1405-1409.
8. H.M.Sinclair. "Natural" Food for Man. - Qual.Plant Food HUm., 1979, 29, p. 7-18.
9. H.C.Trowell. Recent Developmemts in Dietary Fibre Hypothesеs. - In: "Dietary Fibre: Current Developments of Importance to health". ed. by K.W.Heaton, London, libbey, 1979, p. 1-8.