THESES OF THE DOCTORAL THESIS

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INVESTIGATION OF THE POSSIBILITY OF UTILIZING ANIMAL BLOOD IN THE FOOD INDUSTRY

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Az iskolavezető jóváhagyása A témavezetők jóváhagyása

BACKGROUND AND OBJECTIVES OF THE WORK

Sustainability is a hotspot in both scientific literature and media today. In this context, the utilisation of by-products, or related topics such as circular economy or zero emission, are attracting increased interest from academia, society and thus from trade and industry.

Even the selected parts of the literature reviewed , which are chosen only for the purpose of generating interest, demonstrate the importance and relevance of the topic. The blood of mammals is a by-product of industry, which is produced in very large amount and can represent up to 9 g $(100\ g)^{-1}$ of the total live weight of an animal, which is considerably more than 10 g $(100\ g)^{-1}$ of useful weight (Csurka et al, 2021). According to the Eurostat database, only in 2021, 6 801 910 t of beef and 23 393 670 t of pork were produced in the European Union, and 28 930 t of beef and 462 740 t of pork in our country, 340 095,5 t of beef blood and 1 169 683,5 t of pig blood at EU level, and 1 446,5 t of beef blood and 1 169 683,5 t of pig blood in Hungary, calculated based on the weight ratio of 5 g $(100\ g)^{-1}$ which can be safely obtained by bloodletting using conventional technology. A very limited proportion of this blood was utilised in a high value adding way. If we do not include the blood that is illegally “disappeared", the blood stored as hazardous waste at extra cost and sent for neutralisation is more than 90% of the above presented numbers, in Hungary practically 100% of that. The blood neutralised in this way can at best be used to produce animal feed ingredient or fertiliser based on Regulation (EC) No 1069/2009 and Regulation (EU) No 45/2012. However, in general, the separate storage of blood is not fully solved and it is left in an open system during the slaughtering process, where, based on a hazard and risk assessment, other parts of the carcass, including infectious ones, may be left as well. In the latter case, only the ash of the by-product can be utilized as a raw material for concrete production after neutralization at high temperatures. The reason for this is that the legally compliant technology that allowed for collection of animal blood for human consumption is very expensive and the potential uses are very limited due to lack of knowledge and demand. There was always a lot of potential and 'money' in by-products, but there is still very limited scientific results that industry can use either to boost demand or to increase competitiveness. The literature on blood processing for human consumption, which describes specific technological parameters, is very old, the methodology is not always reproducible and the quality of the results is not always comparable with today's instrumental analysis.

Despite the fact that all the possibilities for the utilisation of blood are available. Especially now, in a world affected by the COVID-19 epidemic and a war in Europe's largest arable farming areas, where, in developed countries as well, food security is once again a relevant issue besides quality starvation. Blood, as the best natural source of iron, can help to prevent and treat the iron deficiency that affects one in every three-four child and woman (especially pregnant woman), and one and a half billion people (Meena et al., 2019). In addition to sustainability and human health aspects, it is also in the economic interest to utilise animal blood in the highest possible quantities and with high added value. The global healthcare and wellness food market size, in which functional foods are the major products, is estimated to reach USD 104.27 billion in 2021 and USD 113.80 billion in 2022, and is predicted to expand at a compound annual growth rate (CAGR) of 9.24% (Research and Markets, 2022), reaching USD 177.25 billion by 2027. This means that by 2027 it will reach USD 177.25 billion. Moreover, not only will this increase the market for healthcare and functional foods, but the meat industry, which is facing increasing challenges and uncertainty in Hungary, could also increase its competitiveness.

Both nutritional value [high biological value high protein content (Sorapukdee & Narunatsopanon, 2017; Ockerman & Hansen, 2000; WHO &

UNU, 2007) and high heme-iron content (Gorbatov, 1988; Satterlee, 1975; Tybor et al, 1973)] and techno-functional properties, animal by-products, especially blood, which is the subject of my work, can be perfect raw material of functional and common foods (Bah et al., 2013; Duarte et al., 1999; Ofori & Hsieh, 2012; Toldrá et al., 2012), depending of course on the definition of functional foods (Doyon & Labrencque, 2008).

In my doctoral thesis, I aimed to gain and publish this increasingly missing knowledge to help increase the utilisation of blood in a high added value way. Another objective is to enhance the nutritional benefits of different foods by using blood to improve or maintain their techno-functional and organoleptic properties to meet industrial and consumer demands.

The objective of my research was to present the technological, nutritional and sustainability properties of animal blood, a currently underutilised but highly valuable and safe resource. The methodology and the results of my experiments have been evaluated with a view to their practical utility. My aim was to provide as much information as possible on the potential uses of blood and the effects of its use in foods on processed food products, in order to be able to recommend as many possible possibilities for the utilisation of animal blood to the food industry. The objectives of my experiments were the followings:

- To optimise some parts of the pre-treatment of animal blood (anticoagulation, separation), which is poorly described in the scientific literature in terms of industrial applicability, by developing a methodology to increase the efficiency and quality of the blood product.
- To investigate the potential of enrichment with animal blood and blood fractions in different food matrixes (meat products, bakery products, dairy products) to improve their nutritional properties by investigating and comparing the quality properties of control and enriched products,

including in their techno-functional and sensory properties (texture, colour, pH, water holding properties, consumer sensory evaluation, consumer preference).

- To investigate the potential of using animal blood plasma and blood fractions for allergen (eggs, milk) substitution in several food matrixes (bakery products, desserts) by analysing and comparing the quality properties of control and allergen substituted products, including in their techno-functional and sensory properties (texture, colour, pH, water holding properties, consumer sensory evaluation, consumer preference).

MATERIAL AND METHOD

My doctoral investigations can be divided into three major parts. I carried out experiments on the processing of raw blood. First, I optimised the first step of blood processing: the inhibition of blood coagulation. In my experiments, I mixed dry trisodium citrate powder into the fresh blood, because adding the anticoagulant in solution add excess water [10 g $(100\ g)^{-1}$ by total weight] into the system. This extra water makes the further processing steps of concentration and drying, which are designed to remove water from the blood, more costly and less efficient. Then I investigated the possibility of separating porcine blood by membrane filtration instead of the more common centrifugation. The factors of the experiment were: 1) membrane pore size (0.8 μm, 1.2 μm), 2) retentate flow rate (200 $l\ h^{-1}$, 300 $l\ h^{-1}$) and 3.) transmembrane pressure (10^5 Pa, 2×10^5 Pa, 3×10^5 Pa).

In the second part, I investigated the effects of different types and amounts of blood product enrichments on the techno-functional and sensory properties of different target matrixes. I aimed to investigate homogeneous, simple, but information-rich real food matrixes. Whole blood powder, haemoglobin powder and blood plasma powder (three levels of factor 1) were added to meat batter based products, cocoa sponge cakes and chocolate ice-creams. Besides collecting information, the objective was to develop functional foods with positive nutritional effects (high, well-absorbed iron content and/or increased protein content). I also carried out a storage experiment for the meat batter products for three months after the day of production with a thirty-day sampling frequency and sponge cakes for three days with daily testing (four levels of factor 2) to see the effect of blood product enrichments on changes during storage. In the case of meat batter products, several enrichments at different concentrations (three levels of factor 3 and, in another experimental design, six levels of factor 2, excluding the type of enrichment as a factor) were applied, based partly on pre-experiments and partly on the literature, as in the other two products. Enrichment concentrations for whole blood powder and haemoglobin powder were determined as 1 g $(100\ g)^{-1}$, 3 g $(100\ g)^{-1}$, 5 g $(100\ g)^{-1}$ for whole blood powder and 1 g $(100\ g)^{-1}$, 3 g $(100\ g)^{-1}$, 5 g $(100\ g)^{-1}$ for haemoglobin powder; and 1 g $(100\ g)^{-1}$, 3 g $(100\ g)^{-1}$, 5 g $(100\ g)^{-1}$, 10 g $(100\ g)^{-1}$, 15 g $(100\ g)^{-1}$ for blood plasma powder. Thus, I set up several different full factorial experimental designs: one for sponge cake and one for ice cream, and two for red products, because I investigated separately the effect of the three different types of blood powder up to 5 g $(100\ g)^{-1}$ and the effect of plasma powder up to 15 g $(100\ g)^{-1}$ on the quality properties. In all cases, the concentration of enrichment was 10 g (100 g)-1 for ice cream and the equivalent of the egg protein content for cake, with the three blood products substituted for the egg.

Then, in the third part, I investigated the possibilities of substitution of two types of animal allergens (egg and milk). I was curious to know how I could substitute milk in dairy products and egg in cakes with plasma protein equivalent to the protein content of the original ingredient (factor 1) by using blood plasma. I analysed the techno-functional and organoleptic properties of the custards after sweetening with sugar and sugar alcohol (factor 2), and the cakes were stored for three days after the day of production (factor 2) and checked daily to investigate changes during storage.

In the field of techno-functional properties, I investigated the texture of fluid products by rotational viscometry by Physica MCR 92, Anton-Paar rheometer with concentric cylinders (CC27), using the Couette type method at variable shear rate. The Herschel-Bulkley model (Mezger, 2006) was well fitted for the behaviour of all my samples. For solid textures, I used a Stable Micro System (SMS) TA. XT Plus texture meter with 50% deformation for texture profile analysis, a cutting (Warner-Bratzler) test, a three-point breaking test and/or stress relaxation measurement depending on the sample type and expected results. Generally, texture and colour gave statistically well-evaluated results, but in addition to these, trend-valued results were obtained by dry matter content measurement based on simple drying to constant weight and mass measurement, water activity measurement with the Novasina LabMaster-aw neo and pH measurement with different types of instruments suited to the sample. Furthermore, I had the opportunity to observe the changes in microstructure due to the enrichment of the meat batter products by scanning electron microscopy.

The sensory evaluation was in most cases a simple consumer preference test. However, for a few products, of which I would like to highlight cocoa sponge cakes in the first row, I have developed a sensory evaluation, not only of preference, but also of the presence or intensity of different types of colours, flavours and texture attributes, which can be objectively rated by a large number of consumers.

RESULTS, CONCLUSIONS AND SUGGESTIONS

To ensure the sustainability of the food industry and the competitiveness of the meat industry, as much animal by-products as possible, especially mammal blood, should be utilised with high added value instead of the more typical wasteful elimination and/or very limited use of animal by-products as regulated by law. Utilisation in the food industry can also provide solutions to problems such as iron deficiency anaemia, which affects a large part of the population, or protein deficiency. My results presented in my PhD thesis clearly show that blood and its properly separated and handled fractions are suitable for use as a food ingredient. Thus, these also offer the opportunity to improve the nutritional properties of foods without negatively changing their organoleptic properties, if used appropriately. As a first step, two main fractions can be separated from whole blood with the minimum of effort: the plasma and the red blood cell (RBC) fraction. Plasma is a good source of proteins, cold binder, gelling, foaming and stabilizing agents, but the plasma obtained directly from the separation of blood has a high salt content, which must be considered because of its impact on techno-functional and sensory properties. RBC is an excellent source of iron and protein, but its iron content gives products a strong black or red colour and a metallic, bloody taste, depending on the treatment, if not used appropriately.

In my doctoral thesis I made two proposals in the field of raw blood processing technology. Firstly, I proposed the use of dry trisodium citrate powder instead of solution in the anticoagulation process. The water content of blood should be removed for better utilization and preservation. However, before removing the water, anti-coagulant has to be added into the blood for preserving the beneficial techno-functional properties. Approved anticoagulants have to be used. The dewatering of blood and blood fractions from mammals (membrane concentration, spray drying, lyophilisation...) can be made cheaper and faster, and the efficiency of transport and storage to dewatering can be increased by not adding extra water during the anticoagulation process. 0.48 g $(100\ g)^{-1}$ of trisodium citrate powder was suitable for inhibiting blood coagulation in the blood, but I observed a membrane on top of the standing material. The lowest trisodium citrate content that can inhibit blood clotting for one day is 2.4 g $(100\ g)^{-1}$ according to my research.

My second proposal, related to pre-treatment and raw blood processing, is the development of membrane separation. Although centrifugal separation is the most widely used, there are potential volumes where the use of membrane filtration may be more efficient and beneficial for blood products. The reason for the later argument is that the quality of the separated blood products can be much better controlled by the filtration parameters proposed based on the results of my research. I have found that the quality of the blood products obtained from porcine blood is significantly influenced by the transmembrane pressure difference, membrane pore size and retentate volume flow rate. However, filtration efficiency was only significantly affected by transmembrane pressure difference and membrane pore size, which means that the retentate volume flow rate can be varied freely without affecting efficiency. Based on information from the literature on microfiltration of porcine blood and my own experimental design, I built a model for the retention of the gel layer on the membrane that best represents the efficiency. I estimated the parameters of the objective function and the effect sizes and successfully determined the global minimum of the objective function, namely the optimum for microfiltration of porcine blood. The optimum efficiency was found for the smallest transmembrane pressure difference and the largest membrane pore size used in the experiments. From the point of view of the quality of the blood products, if the purest plasma and the most concentrated concentrated blood are to be produced, the optimum is observed at a transmembrane pressure difference of 2×10^5 Pa, a retentate volume flow rate of 200 $l\ h^{-1}$ and a membrane pore size of 1,2 μm, but near-optimum conditions are also observed at close factor levels. Other animal species or other filtration systems can be tested and optimised using the same methodology.

In the case of food enrichment, it is clear that different types and amounts of blood products had a significant effect on the techno-functional and instrumentally measured organoleptic properties of meat batter products. The quality of meat batter products can be improved by the effect of blood albumin proteins on texture properties.

The addition of plasma, thus blood albumins, can be used to develop meat products that are harder, more chewable and easier to slice than ordinary red meat. Changes in the microstructure of the resulting texture can be observed and demonstrated by SEM. However, during product development it is important to consider the salt content of the plasma powder, because high salt content may cause undesirable effects on nutritional and organoleptic properties. Haemoglobin may help in the development of functional meat products that may have a role in the prevention and treatment of iron deficiency anaemia and in the diets of sports dieters. In addition, this iron-containing protein is a good colouring agent, helping to create a darker colour in products where consumers prefer a deeper, darker shade. The different colour changes caused by fortification with different types and amounts of blood products can be important for consumers because of both positive and negative preconceptions. The addition of a maximum of 5g $(100g)^{-1}$ of whole blood powder and haemoglobin powder did not make the products unpleasantly black, but rather created a deeper and darker colour that consumers would prefer. Furthermore, the addition of blood powders also made the products harder. A harder and darker product suggests a better quality for some consumers, which was confirmed by the sensory analysis. In addition to sustainability and quality aspects, the use of blood in meat batter products also offers economic benefits through reduced cooking losses and increased water retention.

I also added powdered blood products to cocoa sponge cakes as an egg substitute. The difference in techno-functional and sensory properties of sponge cakes made with powdered egg and blood products can be measured and detected. Some quality properties of the products have been improved by the addition of blood powders, furthermore, the substitution of egg is an advantage for many consumers. A good example of the improved properties is that the texture of cakes made with whole blood powder and haemoglobin powder instead of egg powder was harder and more chewable, and the colour was darker and more saturated than in sponge cakes made with egg powder. The darker and more saturated colour gave consumers the impression that the samples contained more cocoa. Plasma powdered sponge cakes were more similar to common sponge cakes made with egg powder, due to the similar albumin content and the lack of hem-iron. Dry matter content and water activity were at desirable levels in all sample groups. Due to drying and changes in colloidal structure, all sample groups became harder and more chewable during storage for three days under normal conditions. However, this change was so small that it could only be detected by instrumental measurement and did not affect the final quality of the product. The differences in texture and organoleptic properties of the sponge cakes made with egg powder and different blood powders were not or were only barely detectable by untrained panel members (consumers). An interesting observation was the sensory analysis of differently coloured samples which were in all other features equal. The untrained panellists found that the two groups of samples containing the same ingredients were different in their perception of the other characteristics of the two samples, in addition to colour, because of their different bias based on different appearance. There were no best cakes for all attributes, but only cakes that were more fit for purpose. If the aim is to replace the egg powder with the least change in colour and texture, the best choice based on the results of the experiment is the blood plasma powder. But in addition to colouring issues, egg powder can also be replaced by whole blood powder and haemoglobin powder because consumers do not feel any difference between the different cakes. If the aim is to develop a harder, less brittle cake that can stand more fillings or stand rougher handling, then a cake made with haemoglobin powder would be the best choice. Whole blood and haemoglobin in cakes and desserts are acceptable to children, so my results may provide important information on the prevention and treatment of iron deficiency anaemia. And a harder, less broken sponge cake can have special shaping properties when making desserts for children.

There is no doubt that ice cream is a very popular dairy product that can be the perfect matrix for investigating the utilisation and effects on product properties of various animal products and by-products with high biological value. Moreover, children prefer this food, so the animal by-product used in it may be more acceptable to them if its positive properties are highlighted. When fortified at a concentration of 10 g $(100\ g)^{-1}$, whole blood powder and haemoglobin powder significantly increase the iron content of chocolate ice creams, but at this concentration cocoa covers iron fat and the colour is not affected by the thermally coagulated haemoglobin. At the same concentration, however, the blood plasma powder is able to change the organoleptic properties because of its high salt content. This was considered by some consumers to have a positive effect on taste, but the majority of consumers did not consider the effect of plasma powder to be positive based on the organoleptic rating. Despite this, it can be concluded that a more flavourful ice cream with a higher protein content can be produced by adding plasma to an appropriately selected target group. The addition of plasma powder to ice cream may be more relevant in the frozen solid state, for ice creams, due to the hardening effect of the texture.

I examined the subject of allergen substitution further. In all cases, the aim was to replace an allergenic food ingredient with hypoallergenic animal blood, as far as we know at the moment. My results show that the allergenic egg powder can be substituted by plasma powder in sponge cake, but that changing the ingredient has an effect on some properties of the product. When I compared the instrumentally measured sensory properties of different types of cakes, cakes made with blood plasma powder were found to be harder and firmer than egg sponge cakes. These properties may make sponge cakes made with blood plasma more suitable for specific applications, such as cake sculpting, or for making harder cakes that can stand higher filling loads or rougher handling in the trade and supply chain. The colour of the sponge cakes made with blood plasma powder was significantly different from the samples made with egg with conventional and industrial technology, but this was not a large difference in nominal terms: the samples were relatively similar to the human eye. The water activity remained close to the critical value of 0.86, which is the lowest water activity value at which human pathogenic microorganisms (coagulase positive *Staphylococcus aureus*) can produce toxins (Deák et al., 2006). The moisture content also remained at the desired level. Consumer sensory evaluation of the samples without egg powder was also adequate. Product development to replace the egg allergen was successful.

I have investigated the possibilities for substituting milk protein as an allergenic component in a custard matrix. In this case, the use of blood plasma instead of milk caused a significant change in the organoleptic and technofunctional properties measured by instrumental methods, which was confirmed by sensory analysis. The protein source used and the sweetener used determined the colour, pH and texture of the final product. The colour change caused was clearly visible to the naked eye and the taste change was organoleptically perceptible. However, as all samples were almost white and the taste of the custards was quite natural, so additional flavouring and/or colouring may mask this change. Based on these results, I would like to highlight an important suggestion for the substitution of milk protein with blood plasma protein: the plasma concentrate or plasma powder should have a reduced salt content, because the blood has a high salt content and is concentrated in the plasma fraction. This causes a significant change in taste.

SCIENTIFIC NOVELITIES

1. I have found that the addition of dry trisodium citrate at a concentration of 2.4 g (100 g)-1 into porcine blood inhibits coagulation, and 0.48 g $(100\ g)^{-1}$ also has an anticoagulant effect, but a surface membrane is formed. This type of anticoagulation allows a faster and cheaper raw blood processing.

   Published: Csurka, T., Pásztor-Huszár, K., Tóth, A., Pintér, R., Friedrich, L. F. (2020): Investigation of the effect of trisodium-citrate on blood coagulation by viscometric approach. In: *Progress in Agricultural Engineering Sciences*. 16 (S2) 19-26. p. DOI: https://doi.org/10.1556/446.2020.20003
   [Q3; cit/doc(2019-2020): 0,696]

2. I defined an objective function for optimizing membrane separation, which I used to estimate the global optimum of membrane filtration at a transmembrane pressure difference of 105 Pa and a membrane pore size of 1.2 µm at any retentate volume flow rate. In terms of the difference in dry matter content of blood products, the optimum was observed at 2×10^5 Pa transmembrane pressure difference, 1.2 µm membrane pore size and 200 l h^{-1} retentate volume flow rate between the factor levels that were applied.

   Published: Csurka, T., Varga, Á., Ladányi, M., Friedrich, L. F., Pásztor-Huszár K. (2022): Membrane separation of porcine blood for food industrial use of permeate and retentate. In: *Journal of Food and Nutrition*

Research, Published online 18 July 2022 (Elérhető: https://www.vup.sk/en/index.php?mainID=2&navID=34&version=2&volume=0&article=2274) [Q3; cit/doc(2020-2021): 1,250]

3. The addition of whole blood powder and plasma powder into meat batter products above a concentration of 5 g (100 g)$^{-1}$, based on parallel production with the recipe applied, results a product that is on average 14% harder, 18% more chewable and needs 15% more cutting power. At concentrations of 3 g (100 g)$^{-1}$ and below, blood plasma powders do not cause significant changes in the texture. The addition of 10 g (100 g)$^{-1}$ of blood plasma powder increases the hardness and the chewiness by an average of 92% and 123%, while the addition of 15 g (100 g)$^{-1}$ increases the hardness and the chewability by an average of 123% and 177% compared to the control meat batter product. When enriched with whole blood powder and haemoglobin powder, the lightness decreased by an average of 35%, 50% and 56% along a hyperbolic trendin case of enrichment at concentrations of 1 g (100 g)$^{-1}$, 3 g (100 g)$^{-1}$ and 5 g (100 g)$^{-1}$.

   Published (1): Csurka, T., Pásztor-Huszár, K., Friedrich, L. F. (2022) Comparison of products made of meat batter with different type and quantity of blood products. In: *Journal of Food and Nutrition Research*, megjelenés alatt [Q3; cit/doc(2020-2021): 1,250]

   Published (2): Csurka, T., Tóth, A., Friedrich, L. F., Pásztor-Huszár, K. (2022): Comparison of products made of meat batter with different quality and quantity of blood products based on their techno-functional attributes. In: *Journal of Hygienic Engineering and Design*, 39 160-168. p. (Elérhető: https://keypublishing.org/jhed/jhed-volumes/jhed-volume-39-fpp-12-tamas-csurka-adrienn-toth-ferenc-laszlo-friedrich-klara-pasztor-huszar-2022-comparison-of-products-made-of-meat-batter-with-different-quality-and-quantity-of-blood/?) [Q4; cit/doc(2020-2021): 0, 438]

4. Blood powder, haemoglobin powder and plasma powder can be used to substitute egg powder in the development of cocoa sponge cake texture when added in the amount with equivalent protein content to the protein content of the egg powder (3%) in the recipe. Whole blood powder (1,5%) and haemoglobin powder (1,5%) also reduce the lightness of sponge cakes. Substitution of egg with plasma powder (1,9%) does not cause any colour change.
   Published: Csurka, T., Varga-Tóth, A., Kühn, D., Hitka, G., Badak-Kerti, K., Alpár, B., Surányi, J., Friedrich, L. F., Pásztor-Huszár, K. (2022): Comparison of Techno-functional and Sensory Properties of Sponge Cakes Made with Egg Powder and Different Quality of Powdered Blood Products for Substituting Egg Allergen and Developing Functional Food. In: *Frontiers in Nutrition*, 9:979594.
   DOI: https://doi.org/10.3389/fnut.2022.979594 [Q1; cit/doc(2020-2021): 6,008]
5. Egg powder can be substituted in sponge cakes (13,2%) by plasma powder (8,4%) with the same protein content. The hardness of the product is increased by an average of 222% and the compressive stress required to break it by an average of 51%, based on parallel productions using the recipe applied.
   Published: Csurka, T., Szücs, F., Csehi, B., Friedrich, L. F., Pásztor-Huszár, K. (2021): Analysis of several techno-functional and sensory attributes upon egg allergen ingredient substitution by blood plasma powder in sponge cake. In: *Progress in Agricultural Engineering Sciences*, 17 (S1, 87-98. p. DOI: https://doi.org/10.1556/446.2021.30011 [Q4; cit/doc(2020-2021): 0,435]
6. In terms of the texture-forming effect, milk can be substituted in custard with blood plasma powder diluted to the same protein content. The same rheological model describes the rheological behaviour of milk and plasma

custard, although their rheological constants are significantly different. The addition of sugar and sugar alcohol as sweetening material significantly changed the texture of milk and plasma custard in opposite ways. The colour and pH of the milk and plasma custard were significantly different.

Published: Csurka, T., Szücs, F., Csehi, B., Friedrich, L. F., Pásztor-Huszár, K. (2021): Substitution of milk allergen ingredient by blood plasma powder in custard with different sweeteners. In: *Progress in Agricultural Engineering Sciences*, 17 (S1) 77-85. p.

DOI: https://doi.org/10.1556/446.2021.30010 [Q4; cit/doc(2020-2021): 0,435]

A PUBLICATIONS OF THE AUTHOR RELATING TO THE SUBJECT OF THE DOCTORAL THESIS

- Csurka, T., Pásztor-Huszár, K., Tóth, A., Pintér, R., Friedrich, L. F. (2020): Investigation of the effect of trisodium-citrate on blood coagulation by viscometric approach. In: *Progress in Agricultural Engineering Sciences*. 16 (S2) 19-26. p. DOI: https://doi.org/10.1556/446.2020.20003 [Q3; cit/doc(2019-2020): 0,696]
- Csurka, T., Varga, Á., Ladányi, M., Friedrich, L. F., Pásztor-Huszár K. (2022): Membrane separation of porcine blood for food industrial use of permeate and retentate. In: *Journal of Food and Nutrition Research,* Published online 18 July 2022 (Elérhető: https://www.vup.sk/en/index.php?mainID=2&navID=34&version=2&volume=0&article=2274) [Q3; cit/doc(2020-2021): 1,250]
- Csurka, T., Pásztor-Huszár, K., Friedrich, L. F. (2022) Comparison of products made of meat batter with different type and quantity of blood products. In: *Journal of Food and Nutrition Research*, megjelenés alatt [Q3; cit/doc(2020-2021): 1,250]
- Csurka, T., Tóth, A., Friedrich, L. F., Pásztor-Huszár, K. (2022): Comparison of products made of meat batter with different quality and

quantity of blood products based on their techno-functional attributes. In: *Journal of Hygienic Engineering and Design*, 39 160-168. p. (Elérhető: https://keypublishing.org/jhed/jhed-volumes/jhed-volume-39-fpp-12-tamas-csurka-adrienn-toth-ferenc-laszlo-friedrich-klara-pasztor-huszar-2022-comparison-of-products-made-of-meat-batter-with-different-quality-and-quantity-of-blood/?) [Q4; cit/doc(2020-2021): 0, 438] → Mivel megjelenés alatt van, nem számoltam rá kreditet.

- Csurka, T., Varga-Tóth, A., Kühn, D., Hitka, G., Badak-Kerti, K., Alpár, B., Surányi, J., Friedrich, L. F., Pásztor-Huszár, K. (2022): Comparison of Techno-functional and Sensory Properties of Sponge Cakes Made with Egg Powder and Different Quality of Powdered Blood Products for Substituting Egg Allergen and Developing Functional Food. In: *Frontiers in Nutrition*, 9:979594. DOI: https://doi.org/10.3389/fnut.2022.979594 [Q1; cit/doc(2020-2021): 6,008]
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