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A Review of Slaughterhouse Blood and its Compounds, Processing and Application in the Formulation of Novel Non-Meat Products

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Abstract

Animal blood has become of growing interest, and its functional and nutritional properties are being exploited. In recent years, several research papers related to the application of blood in food products have been published. The purpose of this review is to describe animal blood, its chemical composition, sampling, processing, preservation, and its application in various non-meat products. Bovine, pig and guinea pig blood has been used in the formulation of different foods such as chocolate, cookies, sausages, drinks, gummies, extruded products and consumed directly as a nutritional supplement, the compounds of interest being heme iron from hemoglobin, blood plasma and serum, bioactive proteins and peptides. However, animal blood residues have a high microbial load that is controlled in slaughterhouses. Likewise, the use of this by-product has

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shown an increase in hemoglobin levels in pregnant mothers and children with anemia who consume it. These fortified foods were high in protein and iron. The use of blood in different food matrices is a potential alternative to improve its nutritional quality, in addition to helping to reduce the levels of malnutrition and anemia in people.

Introduction

The blood production as a by-product of the meat industry is very high, due to the large number of animals that are slaughtered in slaughterhouses. Slaughterhouses generate large volumes of blood as part of the process of slaughtering and bleeding animals,[1] as described in Table 1, and approximately 3 to 5 liters of blood can be collected per 100 kg of body mass.[2] Likewise, per living body or slaughtered mass. The average blood yield of 4,5% for the cattle and 3,5% for pig of the animal live weight has been accepted in the meat industry worldwide.

Table 1: Average slaughterhouse blood production in different countries

Country	Animal	Slaughterhouse blood production for year	Authors
USA	Bovine, Swine and Chicken	7 to 11% blood of 41.8 million tons	3
Argentina	Poultry	150 million liters	4
Mexico	Slaughtered animals	275 thousand tons	5
China	Pork	1 500 000 tons	6
Korea	Slaughtered animals	70 000 tons	7
Australia	Bovine	120 million liters	8
United Kingdom	Slaughter animals	100 thousand tons	9

According to the literature, blood is discarded in most cases, losing a by-product with high nutritional value and functional properties,[4,5,6] due to its high content of protein and heme iron, which can be more easily absorbed by the human body compared to non-heme iron from vegetables.[10,11] In addition, the other bioactive compounds it contains may have beneficial effects on health, such as bioactive peptides with antioxidant, antihypertensive and anti-inflammatory activity[1,12,13] (Table 2).

Table 2: Blood yields in different animals[14]

	Pig	Lamb	Sheep	Cow	Bull	Ox
Liquid blood (kg/animal)	2.84	1.17	1.76	16.52	18.41	23.0
Blood powder (kg/animal)	0.432	0.193	0.266	2.51	2.80	3.50

Whole blood contains total solids (18-20%), protein (13-15%), water (80-82%), salts (2%), fat, and carbohydrates (<1%),[15] considering proteins as the most important from the nutritional and industrial point of view, being used as additives for the elaboration of new products,[16] In addition, they can be used as stabilizers, clarifiers, emulsifiers, milk substitutes and similars that allow improving the nutritional quality of the food.[7]

When the blood is discharged into the sewers of slaughterhouses, it generates a serious environmental problem of pollution due to its high contaminant load, which can reach a chemical oxygen demand (COD) of 375 000 mg/L^{-1} and biochemical oxygen demand (BOD) of 250 000 mg/L^{-1}. In addition, the processes for decontamination turn out to be very expensive.[6,17,16,18] The use of blood from slaughterhouses helps to reduce this serious problem. It is estimated that approximately 30% of blood is used in the food industry, most of which is used in the meat industry as a natural colorant and gelling agent.[19] The use of animal blood fractions in the food industry worldwide has been increasing, being the compounds of interest, blood plasma and red blood cells.[20]

For this reason, a narrative review was performed using the Scopus, Web of Science, PubMed and Science Direct databases with the keywords "food industry and animal blood or animal blood applications". Studies were searched and selected up to the year 2022.

The objective of this review was to describe the composition of blood from slaughterhouses, examine the conventional and emerging processes to which this by-product of the meat industry is subjected, in addition to evaluate its possible applications in the formulation novel non-meat products.

Slaughterhouse Blood and Its Compounds

In the meat industry, everything that is produced from the animal except the meat or carcass is considered a by-product.[21] The by-products of the slaughtered animals are classified as edible and non-edible, the first refers to the liver, kidneys, heart, tongue and brain and the second the nails, bile, wool, horns, bones and fetus. The lungs, spleen, bladder, rumen, small and large intestine, ears, skin, testicles, animal fat and blood can be edible or not depending on the culture, traditions, religion and eating habits.[22,23] In addition, these by-products have high protein content with potential in human nutrition, being blood recommended as a nutritious and economical product.[20]

Animal Blood

The blood of animals is viscous and is comprised of a suspension of cells such as thrombocytes (platelets), white blood cells (leukocytes) and red blood cells (erythrocytes) present in a colloidal system known as plasma, it has an opaque coloration due to erythrocytes or red blood cells of hemoglobin.[15] The proteins present in the blood have high nutritional and functional value due to their high iron content.[6] Some physical values of the blood are detailed in Table 3, which have been evaluated at the time of sampling.

Table 3: Physical characteristics of animal blood

	Average blood values	Cow	Authors
Density (kg/m^3)	1050	1052	15,24
Viscosity(kg/m.s)	0.0036 - 0.0053	0.42 - 0.0098	15,24
pH	7.5 (temperature 20 °C)		15,25
Freezing point	-0.55 °C		15

Chemical Composition

The chemical composition of animal blood varies depending on the species, as shown in Table 4.

Whole bovine blood has in its composition a protein content of 17.3%, water 80.9%, carbohydrates 0.07%, minerals 0.62% and 0.23% fat. Plasma has water 6.67%, proteins 79.54%, carbohydrates 5.08%, ashes 7.26 % and total lipids 1.45% and in the cellular fraction it presents water 2.29%, proteins 78.16%, carbohydrates 17.27%, ashes 2.05% and total lipids 0.23%.[28]

The animal blood contains 60-70% plasma and 30-40% suspended red blood cells by weight.[6] Blood plasma is the liquid part without the content of blood cells[29] and basically contains 91% water, 7% proteins, 1% mineral salts, it has all blood proteins except hemoglobin.[25] However, it has more than 100 different proteins, of which the most representative are the serum proteins albumin, γ-Globulins, α-Globulins, β-Globulins and fibrinogen,[30] these being used for their different functional properties.[31]

Table 4: Chemical composition of dehydrated blood from different animals

Blood (base seca)	Proximate composition					Minerals						Authors
	Moisture (%)	Protein (%)	Carbohidrates (%)	Fat (%)	Ashes (%)	Iron	Mg	Cu	Zn	Ca	P	
Chicken	2.83	88.27	1.65	0.15	9.93	1816.62 mg/kg of dry weight	387.67 mg/kg of dry weight	26.32 mg/kg of dry weight	42.53 mg/kg of dry weight	-	-	26
Duck	2.71	89.7	0.41	0.43	9.45	1803.06 mg/kg of dry weight	471.15 mg/kg of dry weight	20.74 mg/kg of dry weight	41.5 mg/kg of dry weight	-	-	
Swine	2.19	90.97	0.36	0.86	7.81	1490.14 mg/kg of dry weight	309.93 mg/kg de of dry weight	36.71 mg/kg of dry weight	33.26 mg/kg of dry weight	-	-	
Bovine	6.85	79.18	-	-	4.13	195.46 mg/ 100g	16.50 mg/ 100g	-	-	10.24 mg /100g	130 mg /100g	27

The red blood cell fraction is made up of 34-38% of protein,[31] 61- 63% of water and 1-2% of minerals.[9] Among the proteins included in the fraction of red blood cells, the most important is hemoglobin, which contains heme iron, used to treat some types of anemia, whose level of absorption in the body is 20 to 35% 5. Table 5 shows the composition of whole blood and its fractions.

Table 5: Composition of slaughterhouse blood and its fractions

Components	Whole blood[32]	Plasma, 60% of the blood	Red blood cells, 40% of the blood	Serum, 66% of the blood	Desiccated plasma[9]	Desiccated globin
Water (%)	80.8	90.8	60.8	91.2	2.5-7.0	3.5
Fat (%)	0.2	0.1	0.4	0.1	0-0.15	0
Minerals Salts (%)	0.9	0.8	1.1	0.8	2	1-6
Dry solids (%)	-	-	-	-	96-97.5	96.5
Proteins(%):	17.0	7.9	35.1	7.5	70-96	91-95.4
Albumin	2.2	3.3	-	3.3	-	-
Globulin	2.8	4.2	-	4.2	-	-
Fibrinogen	0.3	0.4	-	-	-	-
Hemoglobin	10.0	-	30.0	-	-	-
Stroma	1.7	-	5.1	-	-	-
Other substances	1.1	0.4	2.6	0.4	-	-

Alternative Processing of Blood From Slaughter-houses

Sampling

Proper blood sampling helps reduce the risk of contamination, which is initially sterile in healthy animals,[33] being able to obtain up to 4% of blood per live weight of the slaughtered animal.[34] The amount of blood that can be obtained from animals varies depending on sex, species and age,[35] likewise, Table 5 describes the yield of blood in different animals.

The amount of blood that could be collected a few years ago was approximately 50%, but today, through appropriate collection systems, 60% can be collected because 15-20% remains in the carcass and 20-25% of blood remains in the viscera.[35] Moreover, there are two blood sampling systems, the first is an open drainage system, in which the blood from the slaughtered animal flows by gravity to the collection tube, however there is the possibility of contamination and the second is the closed drainage system which is aseptic. Aseptic blood sampling is performed through tubes, ensuring a more hygienic and higher quality collection process.[18,33] For hygienic blood sampling, it is recommended to disinfect the slaughter instruments and animal skin, add an anticoagulant solution to the blood stream and immediately cool it by storing it at 5-7 °C.[36]

Stabilization

Blood has a natural tendency to coagulate, however there are anticoagulants that prevent this from happening, such as citric acid or sodium citrate used in a proportion of 3g per liter of blood, and can be used in solid or liquid solution by adding water and acts by converting calcium into a non-ionized form thus preventing coagulation,[9] but if the purpose of the collected blood is to be dehydrated or to produce blood products, it is convenient to use powdered sodium citrate since with this the elimination of water turns out to be faster and cheaper or otherwise the concentration process will be slower and expensive, besides 37 point out that the use of 2.4% (p/p) of trisodium citrate can keep the blood in a liquid state for a day. Another anticoagulant is disodium ethylenediaminetetraacetic acid (EDTA), which is used in a proportion of 2 g per liter of blood and acts by chelating the calcium ion responsible for coagulation and in some cases proteolytic enzymes have been used which cause an anticoagulant effect produced by the proteolytic activity of fibrin[9] or antagonistic substances such as heparin or vitamin K.

Separation of Blood Fractions

Among the methods used to separate the fractions of whole blood, there is the centrifugation method, by which the blood plasma fraction and the red blood cell fraction are obtained and the other method is decantation – separation of the red blood cells from the serum supernatant.[1]

These two methods are described in the Figure 1.

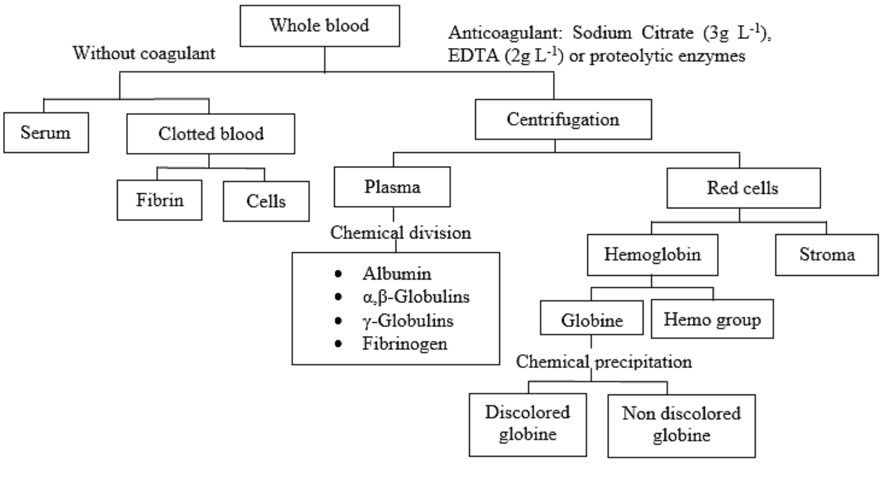

Fig. 1: Separation of slaughterhouse blood fractions adapted from[32,38]

Normally the blood centrifugation process is carried out discontinuously, in a centrifugation container with a certain volume in which the blood is incorporated and centrifuged until its components have been separated by the difference between their specific weights, once it has stopped the centrifugation unit removes the components individually.[39]

Some authors summarized a series of studies performed to separate blood fractions by the centrifugation method whose conditions are described below.[40]

- Centrifugation at 22000 x g /20 °C/20 min
- Centrifugation at 20000 x g/4-6 °C/30 min
- Centrifugation at 5000 x g/10 °C/15 min
- Centrifugation at 3000 x g/8 °C/15 min
- Centrifugation at 2530 x g/4 °C/15min
- Centrifugation at 1020 x g/6 °C/15 min
- Centrifugation at 1000 x g/room temperature/10 min

It also mentions that the different centrifugation conditions at which the blood is separated from its fractions help to improve the concentration of red blood cells (erythrocytes) and increase the yield of plasma, however its quality is reduced, in addition to the ease Separation of blood fractions by centrifugation may vary depending on the species since their blood composition is different.

Preservation of Blood and its Fractions

The blood must be processed quickly after its collection since refrigeration by itself does not guarantee its stability for a long time, however there is the possibility of using biopreservatives that help maintain its physical-chemical and microbiological quality during the storage period, these biopreservatives are associated with lactic acid bacteria (LAB) which have the ability to reduce or inhibit the proliferation of pathogenic bacteria.[18] In addition, another study isolated LAB cultures from porcine blood and dehydrated them by lyophilization and pulverization, maintaining a high number of viable cells that can be used in the biopreservation of blood.[41] Likewise, another research isolated LAB from poultry blood, resulting two strains with compounds similar to bacteriocins capable of inhibiting the growth of *Pseudomonas aeruginosa, Escherichia coli* and some serotypes of *Salmonella spp*., representing a potential and interest in blood bioconservation,[42] likewise obtained strains that generated hydrogen peroxide and antimicrobial compounds such as organic acids. Moreover, *Enterococcus faecalis and Lactobacillus salivarius lactic* acid bacteria in poultry blood prevent the growth of pathogenic bacteria in the first 24 hours of storage (30 °C) and maintain the level of hemolysis stable during the 48 hours, preventing the rupture of red blood cells.[37] However, strain PS99 *Enterococcus raffinosus* with the addition of inulin to pig blood at temperatures of 5 and 15 °C significantly reduces the presence of pathogenic microorganisms (coliforms and *Pseudomonas* spp.), also helps to protect the blood from spoilage, loss of functionality and prevents the effects of a break in the cold chain.[43]

Another way of preserving blood is through the use of high hydrostatic pressure (HHP) techniques, a form of non-thermal disinfection with less affectation of protein functionality, with satisfactory results in the preservation of plasma and red globule fraction and resulting in products of better microbial quality.[17] Other research mentions that a treatment with HHP at 40 °C for 15 minutes and 450 MPa in porcine blood plasma has a greater efficacy in reducing undesirable bacteria without affecting the hardness of plasma gels or water holding capacity However, some structural changes can be observed in their proteins.[44] In addition, treatment with HHP at 20 °C for 15 min and at 400 MPa followed by spray drying on porcine red blood cell fraction, decreases bacterial microbiota 2.5 units and it does not affect the hydration capacity of the gels, but a decrease in protein solubility is observed since both processes denature hemoglobin (Hb), generally considered as an appropriate method to preserve the fraction of red blood cells.[36]

There are other conservation systems for blood fractions such as mechanical processes (reverse osmosis, concentration by centrifugation and filtration) and thermal treatments (lyophilization, direct contact drying, atomization and concentration by evaporation).[32]

Application of Slaughterhouse Blood To Non-Meat Products

This section describes and discusses the application of blood and its derivatives in food formulation.

Table 6: Application of blood from slaughterhouses and its compounds in the formulation of novel foods

Animal	Compound of interest	Derivative or by-product	Quantity used	Formulated product	Results	Authors
Bovine	Whole blood	Blood flour	0.5 g	Porridge	It was evidenced that the blood flour had an iron content of 121.0 ± 5.6 mg/ and its protein content was 80 g/DM, it was also mentioned that fortified porridge covers 54% of the recommended daily intake of iron in children aged 1 to 3 years.	[45]
Bovine	Whole blood	Blood flour	10 y 15%	Extruded product	Produced two formula -tions with 10 and 15% of the by-product, which had an iron content of 31. 87 mg/100g and 38.08 mg/100g, and its protein content was 12.47 g/100g and 13.80 g/100g respec -tively.However, the extruded product fortified with 10% was the most acceptable, and also enough for children aged 4 to 6 years to reach the recommended 12.6 mg of iron per day, which was achieved by consuming 40 g of the formulated product. The consumption of these formulations could prevent iron defici -ency anemia.	[46]
Bovine	Plasma	-	35 g/ 100g	Biscuits	The product had a protein content of 5.22%, which helped to meet protein requirements in school-age children (50 g per day),knowing that it provides 10 to 11% of daily requirements.	[47]
Bovine	Plasma	-	-	Rice-based drink	The product presented a protein content of 2.2 ± 0.2 %	[48]

Bovine	Plasma	-	40 g/ 100g	Cachapa-type food (corn-based tortilla originated in Venezuela)	This amount did not affect the organoleptic characte -ristics of the product, but the protein content increa -sed 82.77% comparing to the control (from 3.54% to 6.47%),in addition to present -ing adequate amounts of essential amino acids, with a protein efficiency index of 2.64.	49
Swine and bovine	Plasma	-	29%	Rice-based beverage	The addition of 29% of bovine plasma in the beverage showed the highest acceptance by consumers, presenting a protein content of 2.47 ± 0.31%, in addition, the consumption of the product covered up to 20% of the protein requirements in children from 8 to 12 years old as established by the FAO (0.99 g/kg daily intake of proteins).	50
Swine	Serum	dehydrated serum	8%	Pancake	The protein content of the product doubled to 12% with respect to the control sample.	51
Bovine	Red blood cell fraction	Dehydrated heme iron	6%	Biscuits	An increase in its protein content (13.5%) was evide -nced in the product, being 1.6 times higher compared to the control and an iron content (19.6 mg/100g) being this 8 times higher than the control, presenting itself as an alternative to increase iron levels in people.	52
Bovine	Red blood cell fraction	Dehydrated heme iron	5.7%	Chocolate	The chocolate presented a content of 8.2 ± 0.34 mg/100g of heme iron and its protein content increased by 72% comp -ared to the control (from 7.25% to 12.47%).	53
					The product presented a very similar content to the previous study of 8.8 mg/100g of heme iron, evidencing that in	54

					both studies that used the same amount of the compound, and very close heme iron contents were obtained. They also mentioned that the addition of heme iron generated some changes in color, however it was sensorially acceptable.	
Bovine	Red blood cell fraction	Dry hydro -lyzed red blood cells	Formu -lation 1 (1.3 g/ 100g) and Formu -lation 2 (2.0 g/ 100 g) in the final product	Sherbet-type bars	The mass fraction of iron for formulation 1 was 0.012% and in formulation 2 it was 0.017%. They men-tioned that red blood cell hydrolyzate is a complex mixture of aminopeptides with heme iron that can be used as an anti-anemic agent in order to prevent iron deficiency in people.	55
Bovine	Red blood cell fraction	Hydrolyzed heme iron	Degree of hydro -lysis of 36.25 ± 0.31%	Milk	The product presented an iron content of 56.92 mg /kg and a protein content of 7.4%, likewise it is menti -oned that the consumption of 250 g covers the daily iron requirement in children from 1 to 3 years of age.	56
Guinea pig	Plasma and red blood cell fraction	Plasma and dehydra -ted red blood cell fraction	10 g/500g (plasma) y 2.5 g/ 500g (red cells)	Biscuits	The product presented an adequate nutritional value with a protein content of 10.26%.	57

Likewise, it was found in the literature that some researchers have formulated products with slaughterhouse blood and given it to people to consume to compare their hemoglobin levels in some presentations, as described below.

Biscuits

A previous study introduced pig blood in chocolate-filled cookies and used non-enriched cookies (placebo) as a control, these enriched cookies administered to 77 adolescents aged 11 to 16 years selected in the study[58,44] consumed the product with a content of 10.3 mg of iron for 7 weeks, whose results showed an increase of 16% in the level of hemoglobin, due to the action of heme iron.

Gummies

Some authors conducted a study with aguaymanto gummies containing 2.5 mL of guinea pig blood[59] and they verified its efficacy taking 33 children between 2 and 5 years old who presented a hemoglobin prior to the intervention of 10.58 g/dL who were given the nutritional supplement for 21 consecutive days and at the end of the intervention had a hemoglobin of 12.65 g/dL, evidencing a favorable effect in the reduction of anemia in children by increasing their hemoglobin levels by 19.6% due to the action of iron.

Nutritional Supplement

Another study carried out a quasi-experimental design with 35 pregnant women who had hemoglobin values of 9.99 ± 0.56 g/dL.[60] They were given a nutritional supplement with a content of 200 g of guinea pig blood three times during a week and for a period of 53 days in each case. At the end of the consumption of guinea pig blood, the increase in hemoglobin was 17%, reaching values around 11.65 ± 0.47 g/dL. In contrast, other research showed that iron is a dietary source with a heme structure that penetrates directly into the cells of the intestinal mucosa in the form of iron-porphyrin,[61] with a high percentage of absorption that increases according to the deficiency of this compound. In addition, the proportion of heme iron in diets is used in low proportions, being its absorption easier than that of non-heme iron, presenting an average absorption in men of approximately 6% and reaching 13% in women of childbearing age.[62]

Isolation of Bioactive Peptides with Health Benefits from Slaughterhouse Blood

The proteins present in food, whether from animal or vegetable sources, in addition to providing amino acids, provide bioactive peptides that have antioxidant activity (help prevent degenerative diseases), antibacterial activity (prevents the risk of infection angiotensin-converting enzyme inhibitor (ACEi) (prevent cardiovascular diseases), anticoagulant (reduce the risk of thrombosis), antihypertensive, opioid and antitumor activity, these being small-sized bioactive compounds of amino acids that are inactive in proteins but are activated by digestion of food or by enzymatic hydrolysis.[6,63] The growth tendency of the use of these bioactive components in dietary interventions and as components of functional foods that help improve people's health has increased.[64]

Another study carried out with bovine hemoglobin identified 17 bioactive peptides by a bipolar membrane electrodialysis process for enzymatic hydrolysis,[65] which presented antibacterial effects against six strains (*L. monocytogenes, K. rhizophila, S. aureus, M. luteus, E. coli and S. Newport*) and for the first time antifungal activity against 5 strains of yeasts and molds (*Penicillium crustosum, Aspergillus Niger, Mucor racemosus, Rhodotorula mucilaginosa and Paecilomyces* spp), in addition, they identified peptides with antioxidant, antihypertensive, bradykinin potentiator, hematopoietic, coronary-constrictor and opioid activity. Similarly, antibacterial peptides (α137-141, α99-105 and α99-106) produced by hydrolysis with pepsin and isolated from porcine hemoglobin had an inhibitory effect on strains *Micrococcus luteus* ATCC 934, Escherichia coli ATCC 25922, Salmonella Newport ATCC 6962.[65,13]

In addition, hydrolyzed fractions of porcine blood (plasma and red blood cells) identified twenty-six bioactive peptides with antihypertensive properties, including RBC7 (TPYPCV), RBC9 (FLCT) and RBC15 (VVYPWR) from red blood cells,[66] which had greater ACE-inhibitory activity, concluding that they can serve as a nutraceutical agent for those with high blood pressure. Another study reported that fractions of sheep, pig, bovine and deer red blood cells presented bioactive peptides after hydrolysis generated with papain, presenting a high oxygen radical reduction capacity and iron reducing antioxidant power, as well as hydrolysis with fungal proteases (FP400 and FPII) were able to inhibit the growth of Staphylococcus aureus, Escherichia coli and Pseudomonas aeruginosa.[31] In addition, hydrolysis of the porcine blood cell fraction obtained, using a membrane reactor and various enzymes yields bioactive peptides with antioxidant activity with a high ACE inhibitory activity of 89%.[67]

Some studies show that animal blood is used in Europe and Asia in products such as blood sausage, blood cake and blood curd21 and that these blood proteins have good functional properties and nutritional value in human food preparation[68,9]

Another study shows that the use of whole blood and/or derived proteins as ingredients in the human food chain poses a minimal risk to food safety in terms of transmission and exposure to blood allergens and pathogens that can be transmitted by it, since these risks are the same as for other foods of animal origin.[19] We therefore believe that the utilization of this by-product as a food ingredient can be maximized and the environmental, economic and nutritional benefits maximized by focusing on the relationship between regulators and manufacturers to work together to strengthen preventive measures such as improved product labeling, develop safer blood collection and processing techniques, and educate consumers to allay their largely unwarranted concerns about this product.

Future Perspectives

The use of animal blood in different food matrices presented high levels of iron and hemoglobin content,[15,6] demonstrating an important functional value in the diet of children, especially those with acute malnutrition, as well as pregnant mothers, people with prolonged periods of menstruation or some typology of anemia, which opens new lines of research in the field of gastronomy and the creation of new healthy dishes available to consumers.

In regards to a homemade diet, the use of animal blood can be considered very effective. Unfortunately, the consumption of animal blood is not sufficiently encouraged, especially in developing countries, which are in great need of this iron. And because of the fact that the use of ferrous sulfate during treatment for iron deficiency in children or adolescents can cause extrinsic black pigmentations in tooth enamel, animal blood is more than a viable replacement.[69] Therefore, the innovation of food businesses should be stimulated towards the varied offer of menus, including the use of animal blood or new formulations of functional and healthy foods. Companies can bet on new products sensorially accepted, it is a pending work.

Conclusions

This review describes the current state of knowledge on the chemical composition, sampling processes, treatment and preservation of animal blood. It has been demonstrated that animal blood is already consumed in several regions of the world, both in developed and undeveloped countries, however, consumption is not massive due to the lack of availability in the markets of these foods elaborated with components of this by-product. In addition, studies have shown that animal blood has proteins of high nutritional value, in addition to its functional qualities that can be used to increase the nutritional quality of foods, both for human and animal consumption. This use is explored in some studies, where the application of animal blood in different food products such as chocolates, cookies, beverages, gummies, extruded products, among others, was discussed. The coloring or allergens in these products can be controlled, as well as the risk of proliferation of microorganisms with proper handling of food as any other animal product. In addition, some studies have shown that the consumption of these products has a positive effect on pregnant women and children with anemia, increasing their hemoglobin levels. In the same way, the use and recovery of animal blood adds value to this by-product of slaughterhouses and implies less waste, which has a positive impact on the environment. In general, it is an opportunity for the development of new research and technology transfer that allow the inclusion of this by-product of high nutritional value with multiple health benefits that can be used by companies in the food sector, researchers and consumers.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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