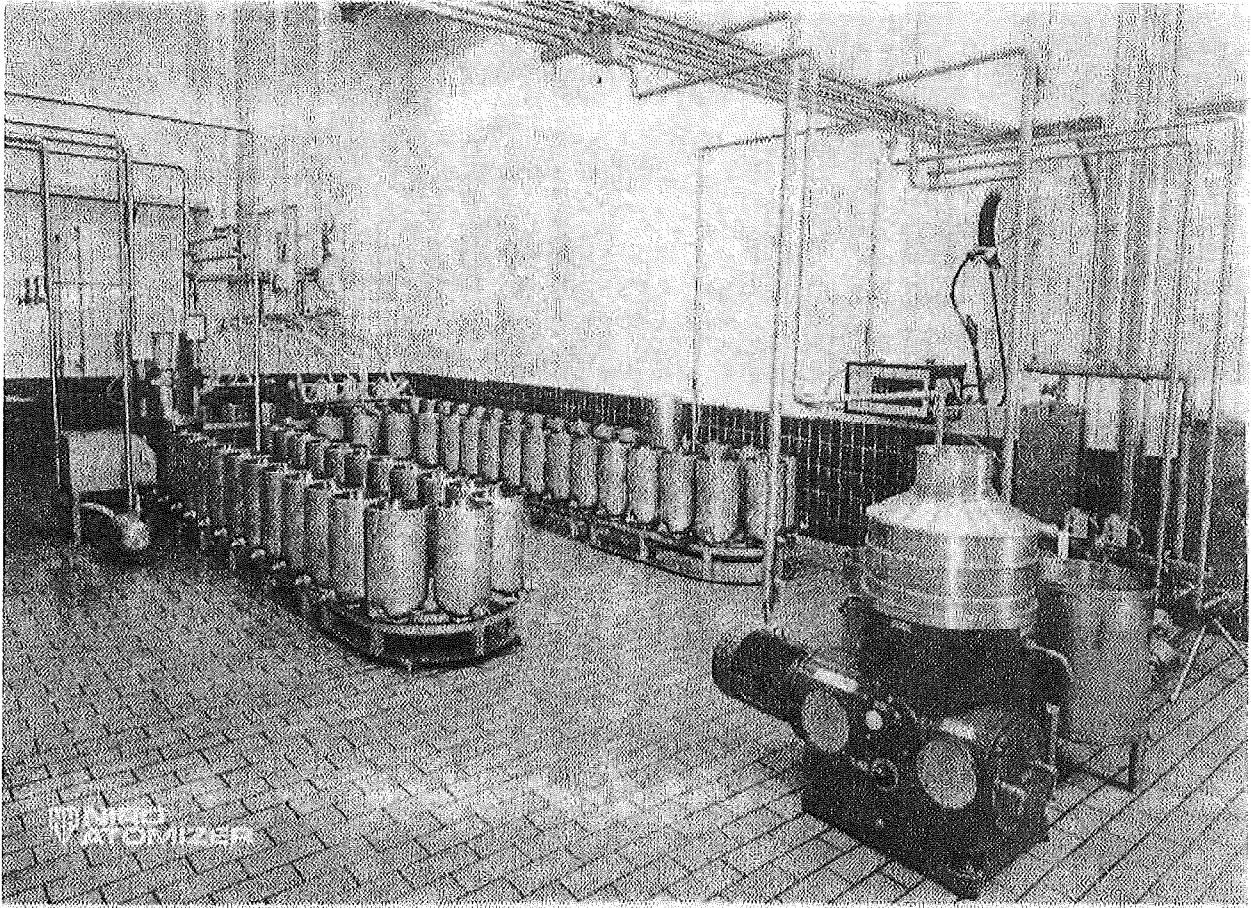


Processing of Sterile Animal Blood Protein for Human Consumption

Copyright Lars Langhoff, B.Sc. (Prod. & Mech. Eng.)

1980 (Redesigned 2003)



INTRODUCTION

Blood - a Valuable Protein Product

In quite a number of countries in the world abattoirs have looked upon blood as a waste product, and as such it has caused great expenses for a.o. installations for treating of the waste water. In more advanced countries, this has led to a production of blood meal and similar products which have been used for animal feed purposes. This is, of course, an advantage, but with a view to the large amounts of protein which we have in blood from abattoirs it is certainly possible to find more optimum solutions for the utilization of the blood.

During the recent years there has been great interest in the utilization of pig and cattle blood for human consumption and some abattoirs have installed equipment which makes it possible to remove the blood in such a way that it can be used for human consumption. Equipment has therefore now been developed which secures efficient identification between the animal and its blood as well as an optimum approval of the blood and efficient cleaning-in-place of all parts coming into contact with the blood before they are used again for the next animals.

Blood is a valuable protein product with the same nutritive value as meat proteins and can therefore be used in quite a number of food products. It is, of course, a condition that the blood is treated correctly.

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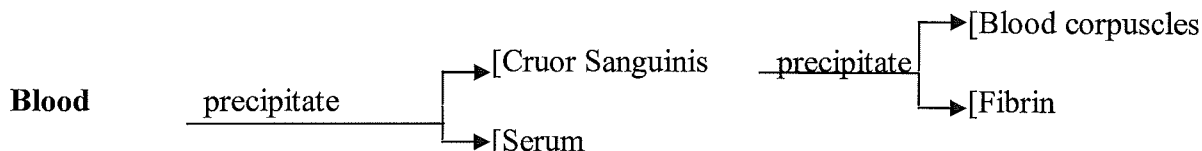
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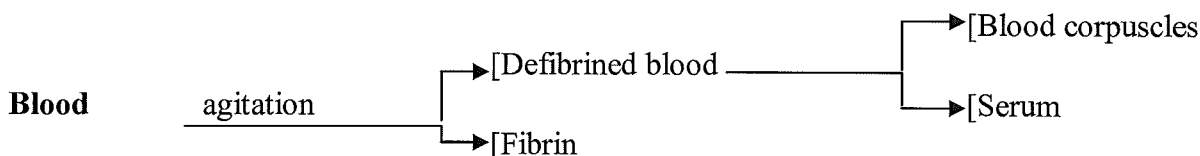
I. Composition of Blood

Blood consists of a liquid called plasma, in which blood corpuscles and blood plates are suspended. Plasma contains dried matter of which fibrinogen is of particular importance, since under certain circumstances it precipitates as fibrin. Plasma, in which fibrinogen is precipitated as fibrin, is called serum.

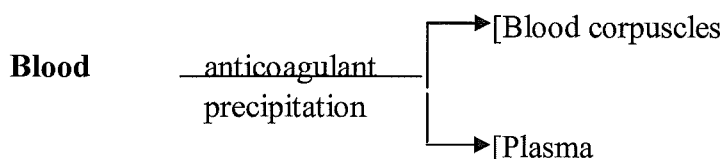
If blood is left unattended for some time, it will precipitate in the following manner:



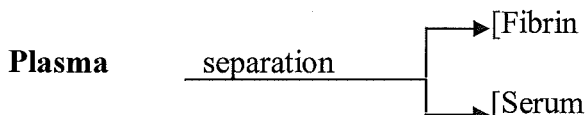
If blood is rigorously stirred immediately after collection, the fibrinogen will precipitate as fibrin, appearing as a fibrous mass which is easily removed by sieving. The remaining defibrinated blood consists of blood corpuscles and serum i.e.



Coagulation of blood is hindered by adding calcium binding additives like citrate, phosphate or oxalate. When left to settle, it will precipitate into 3 layers. The bottom layer contains the heaviest red blood corpuscles, above which is a light grey layer of white blood corpuscles, and on top a clear light yellow liquid - the plasma. The majority of the light blood plates are found in the plasma layer. The blood has, in fact, precipitated in the following way;



If the coagulation hindrance is neutralized, the fibrinogen will be precipitated as a gelatinous mass. The fibrin and the plasma are now separated according to the following manner:



Blood contains approx. 20% dried matter, from which the protein content constitutes approx. 18% and the remainder different kinds of salts. The plasma fraction represents approx. 66% by vol. or 60% by weight of the blood, but contains only 8-9% dried matter and 22% of the total protein. Therefore, the plasma fraction consists of approx. 7-8% protein, 1-2% salts and approx. 91% water.

The remaining 34% by vol. or 40% by weight of the blood consists of cellular matter (red cell fraction) which contains approx. 78% of the total protein. The cellular matter thus consists of approx. 36% protein, 1-3% salts and approx. 62% water.

2. Blood collection

Blood, when collected under strict hygienic conditions, can be used for human consumption instead of for fodder or discharged with effluent waste water.

There are two alternative methods for blood collection:

- (a) the open system and
- (b) the closed cycle hygienic system.

2.1. Open system

The animal is stuck with an ordinary sheath knife, whereupon a blood jug or similar receptacle is held near the point of insertion so that some of the blood is collected. This method has many disadvantages. There is a large wastage of blood, and furthermore there is great risk of infection due to blood contact with the surface of the animal and with the surroundings.

2.2. Closed cycle system

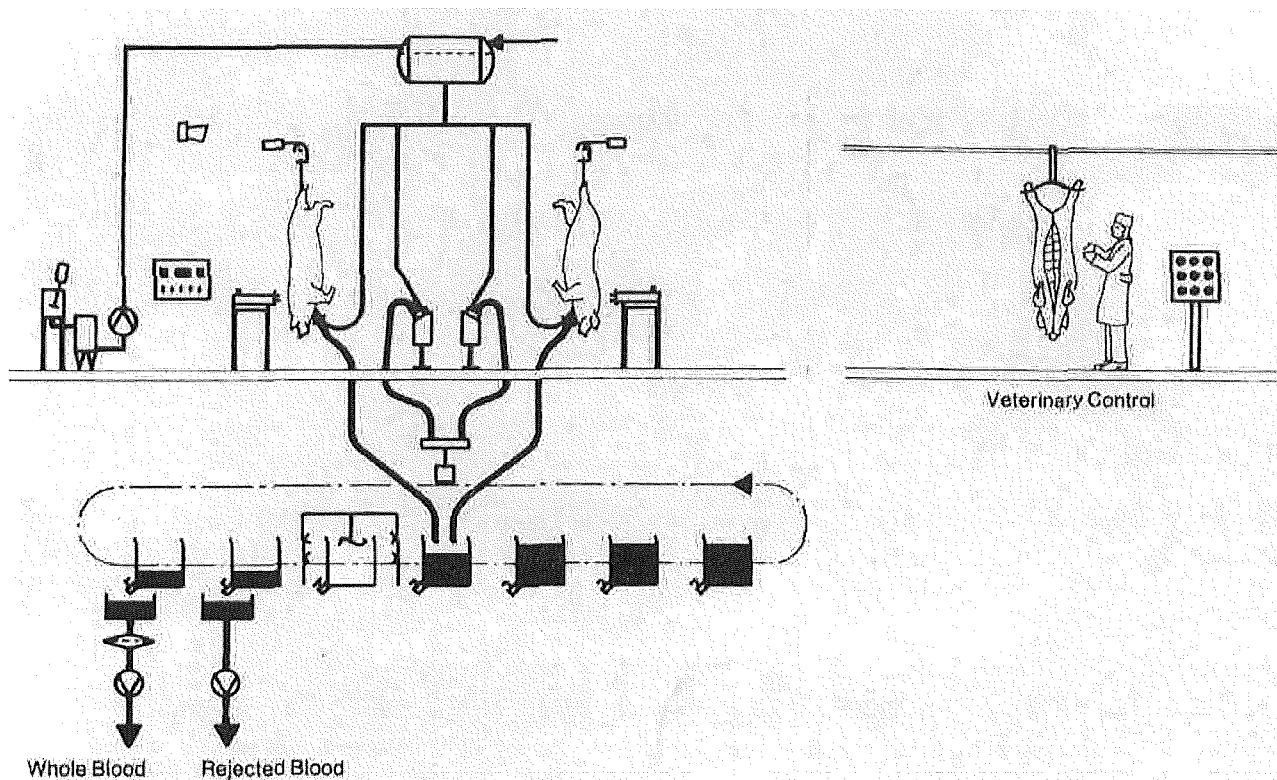
This uses a closed cycle system at the collection point, involving transfer of blood in hoses or tubes into a sanitary room. This method implies a high hygienic standard of the blood collection. Problems associated with the amount of germ layers during the various phases of the blood collection process, are prevented by controlled closed cycle processing.

A throat stick knife or cannula is led into the throat of the animal and drawn upwards towards the heart. The veins and arteries are cut near by the heart, and the blood runs via a closed cycle piping system into collection tanks.

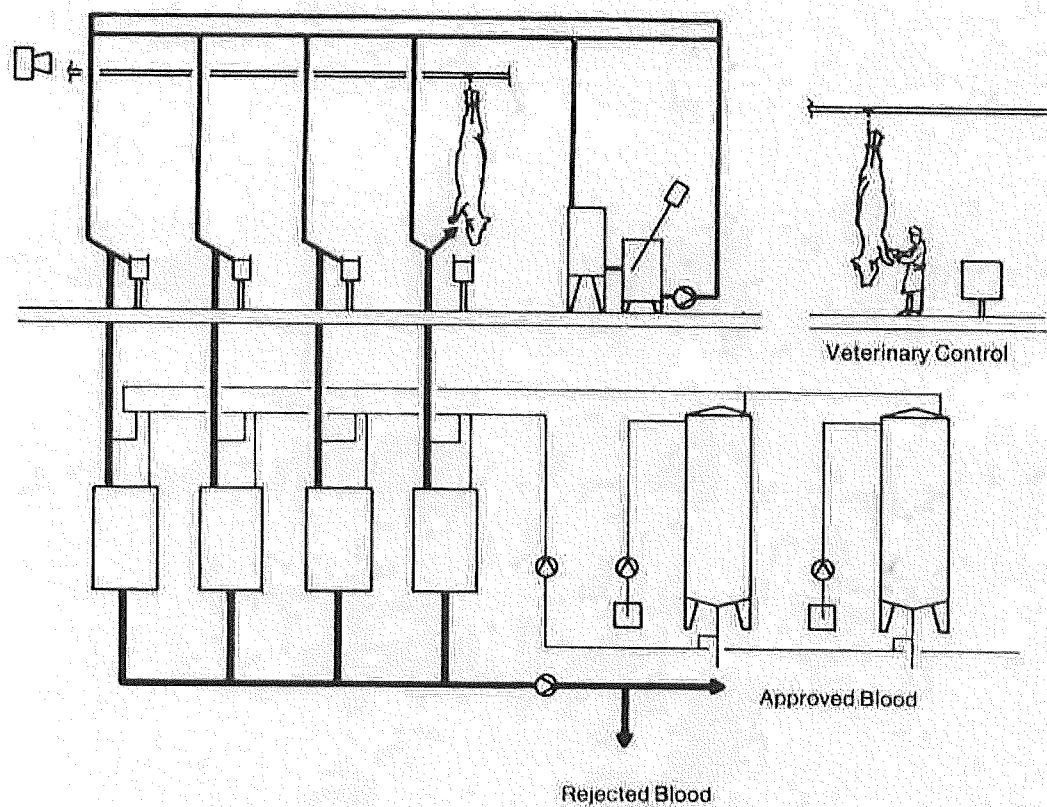
To prevent blood coagulation, an anticoagulation agent is added at the tip of the knife, thereby avoiding coagulum build-up in the pipe system. The amount of anticoagulant added depends on which type is used, 4-8 grams per litre blood for sodium citrate powder is a typical figure.

From "ordinary clean" pigs, blood collection can take place directly, as the knife only touches a very small part of the surface of the pig. If the pig is very dirty, the area into which the knife is led, is cleaned with a dry brush before blood collection.

For cattle and sheep, a patch of skin is cut off at the place of knife insertion. This will secure that the knife enters a sterile area, thus minimizing risk of germ contamination.



Drawing-off and collection of blood from pigs.



Drawing-off and collection of blood from cows.

Today equipment has been developed for drawing-off and collection of blood where special importance has been attached to safe identification of the collected blood and to the control functions which secure that only blood from veterinary accepted animals will be further processed.

The system is controlled by micro-computer so that the veterinary controls the blood together with a constant inspection of the animals and so that blood from a non-accepted animal will not be processed.

The system secures that as much as possible of the drawn-off blood will be used for further processing due to an efficient addition of citrate and due to the fact that only blood from a limited amount of animals is mixed prior to veterinary inspection of the animals.

The blood from one or more animals is collected in intermediate tanks and is held until the veterinary control of each animal has been completed. To secure that only blood from certified animals passes on for further processing, all animals are marked with a sign which clearly refers to the tank in which their blood is stored. If there is blood from one or more animals in a tank, and one of these animals fails the veterinary control or has to be sent for a bacteriological test, all blood in that tank is led to a special tank for processing as technical blood. If on the other hand, blood quality approval has been received the contents of all intermediate tanks are sent to a central tank for further processing.

Knives that have been used on one animal are always sterilized before being used again. This is done to prevent possible germ transfer from one animal to another. After blood collection from a row of animals, all equipment is sterilized after use, even if the blood has been approved. This ensures that the germ count does not increase during the day thus infecting subsequent blood batches.

During blood collection, it is essential that the blood is treated carefully, and there is no contact with water. This causes hemolization, i.e. a bursting of the red blood cells. Such cells at a later separation will bind to the plasma fraction, colouring it red.

When the blood is collected under such careful bacteriological conditions, of closed cycle system collection, it is suitable for human consumption.

It can be used as whole blood, but due to the colour of the blood it can only be employed in limited quantities. However, the blood can be fractionated as mentioned above, i.e. by separating the blood into plasma and cellular haemoglobin fractions.

2.3 Control functions

The first control function takes place just after the animal has been shut or stunned as at this place it is automatically or manually marked so that it is possible to follow the animal through the whole slaughter process. To each mark belongs a certain set of knives for drawing-off the blood and a certain vessel for collecting of the blood. The knives which are not in use are locked in their positions and cannot be taken out until the corresponding mark has been taken into use.

Through the counter which counts how many animals are to have the same mark, it will be

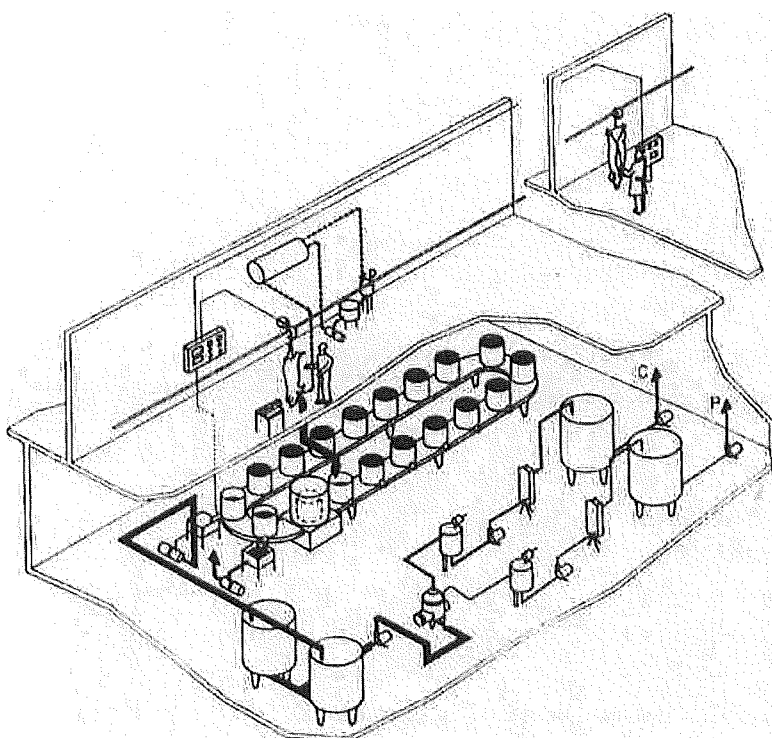
registered when it is time to shift for a new mark.

The veterinary has a control desk with a button for each mark to be used, and from the desk a signal is given to the controlling computer stating whether the blood corresponding to a certain mark is to be processed or refused.

The signal for refuse given by the veterinary cannot be cancelled by a later given signal, but refused animals can be taken into the system again by a signal from another control desk at the veterinary in charge of re-examination. In this way a maximum control is secured, and at the same time the maximum amount of the blood has a possibility to be approved and thus processed.

The micro-computers are operated by the veterinary directly from the control desk, and here it is decided whether the blood is to pass on as approved or rejected. In case of pipe rupture or power failure, the micro-computer will react automatically and reject all blood in the system until the defect has been straightened out.

In order to secure that no blood from one mark comes into contact with blood from another mark prior to approval, all parts which have been in contact with the blood will automatically be sterilized before being taken into use again. If the sterilization process for some reason should fail, a signal is given by the micro-computer which secures that no more blood is drawn-off before the defect has been straightened out.



Collection, control and separation of blood

The installation is equipped with an automatic cleaning-in-place system which secures highest possible bacteriological standard of the blood during the whole process and also minimizes the risk

of blood remaining in the pipe bends, etc. Via the control panel the operator may choose which parts of the equipment are to be cleaned and in which order. The whole cleaning-in-place process only takes 1½ hours per working day (maximum 16 running hours per centrifuge without cleaning).

Blood collecting equipment as described operates fully automatically as the micro-computer operates the whole installation based upon the coded information such as number of animals per container, number of animals to be slaughtered per hour, etc. The system therefore only needs a superior manual supervision.

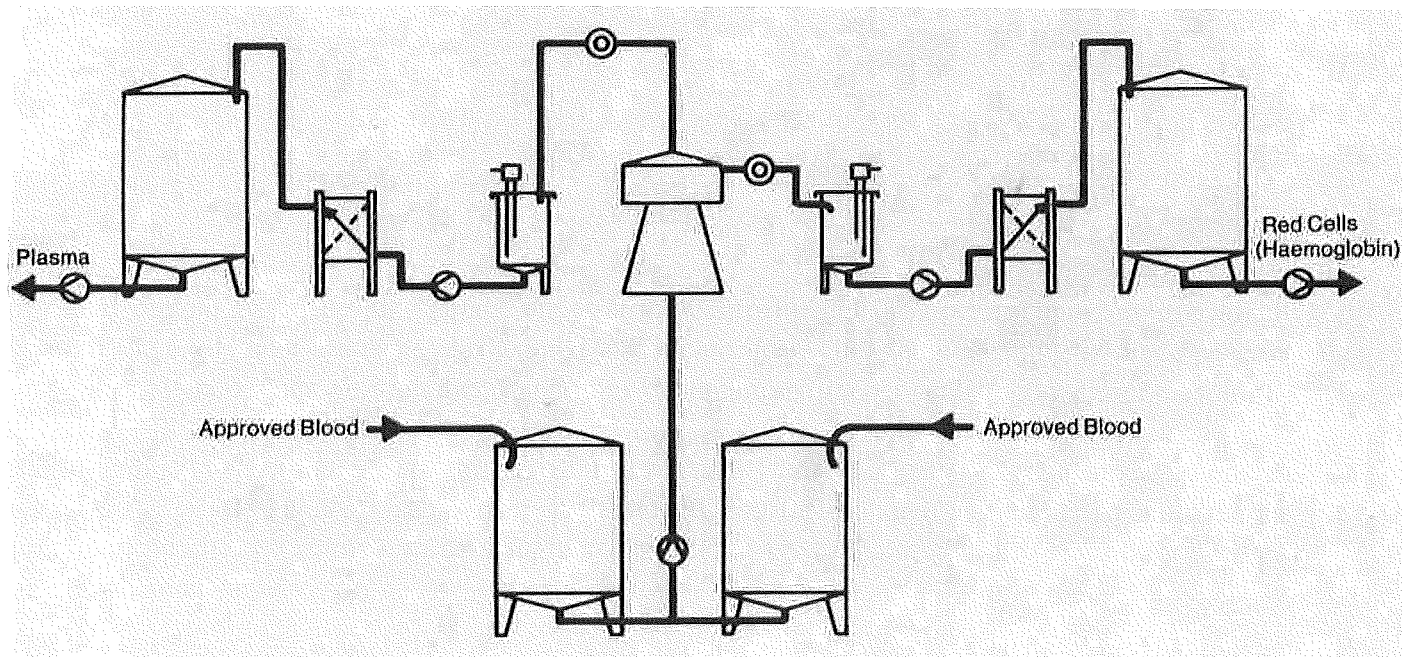
3. Blood Processing

3.1 Whole blood.

Whole blood can be spray dried following an up concentration from 20% to approx. 35% dried matter. When blood is for human consumption, the temperature of the finished product is held below 80°C. If dried blood is subjected to higher temperatures it will not be 100% resolvable and therefore have a lower commercial value.

3.2 Whole blood separation.

Whole blood can be separated into approx. 60 % plasma and 40 % haemoglobin.



Blood separation system.

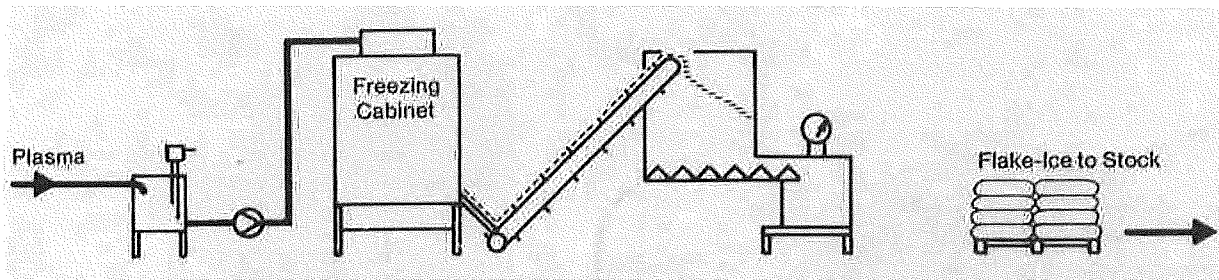
3.3 Plasma processing.

After blood separation, the plasma is cooled down to 4°C prior to immediate use. If it is not used within a few days it has to be processed immediately after separation in order to prevent the germ count becoming too high.

3.4 Plasma freezing.

Freezing the plasma into blocks or in flakes using a rotating flake ice machine can take place immediately after the blood separation.

The temperature of the product must be low (-12°C). When used in minced meat products, the frozen form can be added directly to the mincer as this helps to keep the temperature down.



Freezing of plasma.

3.5 Plasma concentration.

The concentration of plasma or hydrolysate takes place in either an evaporator, which operates at low temperature and low energy consumption (applying thermo-compression), or by means of membrane filtration in hyper-filtration or ultra filtration units.

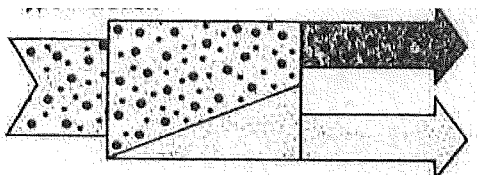
By evaporation the plasma is concentrated from approx. 9 % total solids to 28-35 % total solids.

3.5.1 Plasma concentration by filtration.

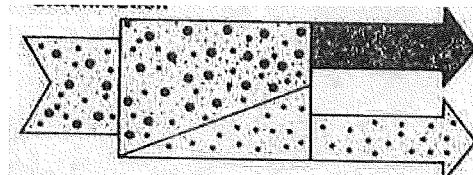
By hyper filtration a substantial part of the water is removed and a product is obtained having a content of 22% total solids, i.e. comparable to meat proteins.

By ultra filtration a substantial part of the water and 80% of the salt is removed so that the product is desalted and contains 22% total solids.

If ultra filtration is used the ash content is reduced, as the greater part of the mineral salt content is removed. However, the plasma does not separate into fibrin and serum, because the calcium ions Ca^{++} are also removed.

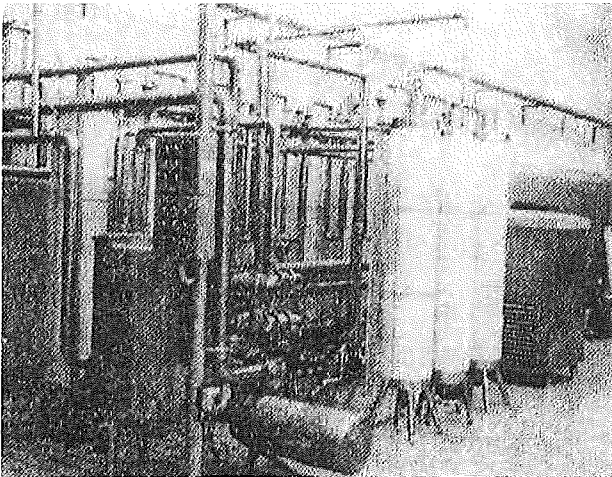


Hyper filtration.



Ultra filtration

● Large molecules ● Small molecules . Water

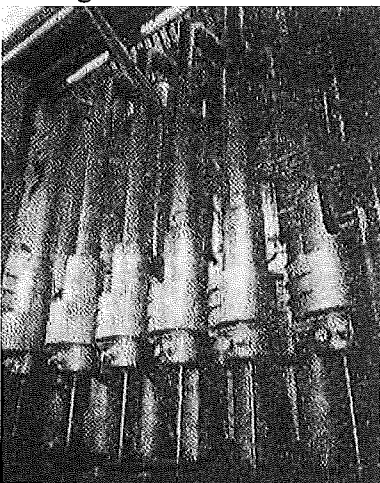


Membrane filtration.

3.5.2 Concentration by evaporation.

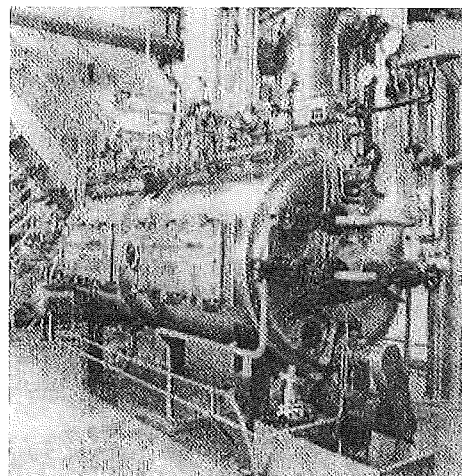
The concentrated product can be used in liquid form or be further processed by flake freezing or spray drying.

Falling film 28 %



Falling film evaporation.

Rotary thin-film concentrator (RTC) 35 %



Rotary Thin film (RTC) concentration

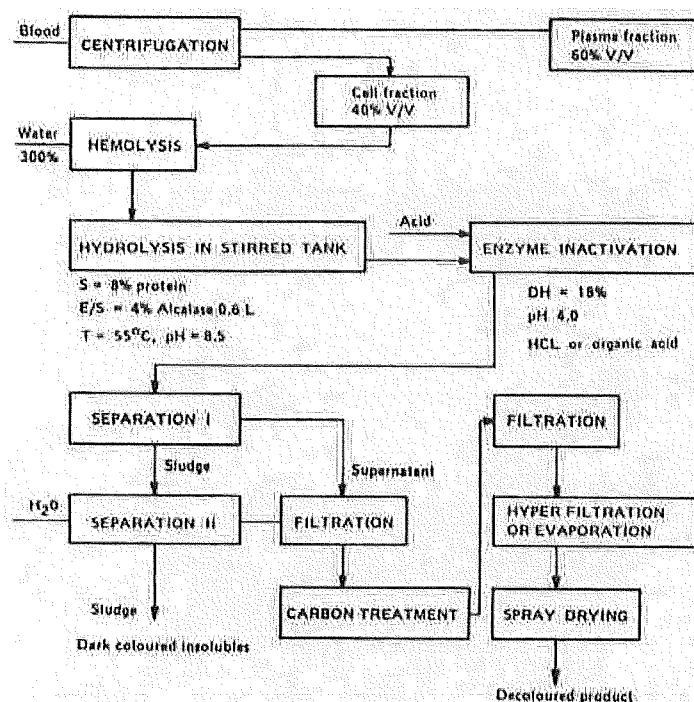
Both concentrated and non-concentrated plasma can be used in liquid form or be frozen and used as scale ice. Furthermore, concentrated plasma is particularly suitable for spray drying.

3.6 Red cell fraction

The red cell fraction with its content of approx. 37,5% dried matter can be spray dried without preconcentration. A very high protein content powder is produced. Like plasma, it can be stored for a long time if the water content is below 10%.

Red cell is limited in use to victuals due to its strong red-brown colour. This colour can be removed by enzymatic treatment. The produced globin powder, which has the same colour as dried albumen, contains approx. 86% protein in dried form. It is used primarily as additive in meat products so as to raise the protein content and overall nutritive value of the foodstuff.

4. Decolouration Process. Decolouration of Blood by Enzymatic Modification



S = concentration of substrate
 E/S = enzyme dosage
 T = temperature
 DH = degree of hydrolysis

The principle of the decolouration process.

4.1 Enzymatic decolouration of blood.

The freshly collected blood to which anticoagulation has been added is fractionated into plasma and cells by centrifugal separation. The plasma fraction may either be recovered separately or dried or frozen together with the decoloured cell fraction.

The cell fraction is haemolysed simply by addition of water (minimum 200%) which also ensures an optimal protein concentration during the enzymatic treatment and the subsequent purification processes. A protein content of 8% (Nx6.25) is reached by addition of approx. 300% water, but the protein content should be controlled by an assay procedure.

The hydrolysis is carried out at 55°C, pH 8.5, using an Alcalase dosage of about 25 Anson units per kg protein (Nx6.25). DH = 18% will be reached in about 1 hour.

The enzyme is inactivated by addition of acid to pH 4.0 and maintaining the temperature at 55°C for at least 30 minutes.

pH is then re-adjusted to 4.5 and the reaction mixture separated by means of ultra filtration and diafiltration is washed once with water in order to improve the protein yield, and the two supernatants are mixed and filtered. A light-brown coloured solution is then obtained.

The remaining colour may be removed by treatment with activated carbon. Using an amount of carbon of 1 kg per 100 litres of hydrolysate at pH = 4.5, 55°C for 60 minutes, the filtered solution appears light yellow.

The thus "polished" hydrolysate may then be concentrated by hyper filtration (reverse osmosis) before being spray dried separately or after mixing with the plasma fraction recovered previously.

4.2 Protein Yields

Using the parameters mentioned above the protein yields shown in the table, based on whole blood or on blood cell fraction, were calculated from pilot plant experiments performed at NOVO. In practice the yields may vary because of variations in substrate composition and quality. The overall yield of protein hydrolysate should, however, be above 70% based on the blood cell fraction.

Results obtained in Novo's Pilot Plant.	Protein yield based on whole blood (%)	Protein yield based on blood cell fraction (%)
Whole blood	100	na
Blood cells	72	100
Plasma	28	na
Blood cell hydrolysate		
One separation (incl. carbon treatment and hyper filtration)	37	51
After recombination with plasma fraction and spray-drying	64	na
Combined hydrolysate (one wash) (incl. one wash of sludge, carbon treatment and hyper filtration)	51	85
After recombination with plasma fraction and spray drying	75	na

5. Drying methods applied in Blood Processing

The designation "dried blood" is normally applied for products attained by drying of drained or pressed coagulated blood or for dried whole blood. Soluble dried blood is attained by drying of defibrinated blood at temperatures below the coagulation temperature of the protein, but is also applied for whole blood dried at low temperatures. Afterwards it is quite soluble.

5.1 Steam coagulation

The blood is led to a tank to which direct steam is added. This causes blood coagulation. After draining, the blood is dried either in a dry render or the drained blood is sent through a disintegrator and spray dried.

If steam coagulation is carefully controlled, the drain water contains only approx. 2% dried matter. This dried matter can be led back, if desired, into the process after evaporation.

5.2 Direct Drying

Blood is collected in tanks and transported either under vacuum, or by air pressure or pumping to a specially constructed dry-rendering plant featuring spring blades on the agitator. Instead of spring

blades, large bone pieces can be applied, which prevent the blood from sticking to the sides. When the water content is reduced to approx. 14%, the material is discharged. The bone pieces are removed and the material is cooled. By this method the water content is reduced to 7-10%, and the product is sold as blood flour.

5.3 Spray Drying

5.3.1 Soluble Dried Blood

Soluble dried blood can be made from mechanical defibrinated blood or whole blood that has been maintained at low temperatures. Prior to spray drying, the blood is concentrated under low temperature conditions in a vacuum evaporator. Spray drying of blood represents a quick and sanitary drying method that prevents product quality degradation. The degree of solubility depends upon the drying temperatures used.

Spray dried blood normally contains 7-12 % water, 83.6 % protein, 1.2 % fat and 3.8 % ash. It has a high quality and the germ count is lower than that of product produced by other techniques.

Soluble dried blood is totally soluble (1:1) in water at 21 °C - 6 °C. On dilution, the solution will coagulate at approx. 71°C.

5.3.2. Plasma/Blood Albumin

Prior to spray drying, plasma and blood albumin is generally concentrated in a vacuum evaporator to 28-35 % ^{x)} and 93 % dried solids content. Spray drying is conducted under low temperature conditions, resulting in powders that are fully soluble in water at 43-49 °C. Coagulates on heating commerce's above 71 °C.

The dried powder contains approx. 74 % protein, 7 % water and approx. 19 % salts and dissolves (1:1) in water at 21-32 °C under gentle stirring conditions.

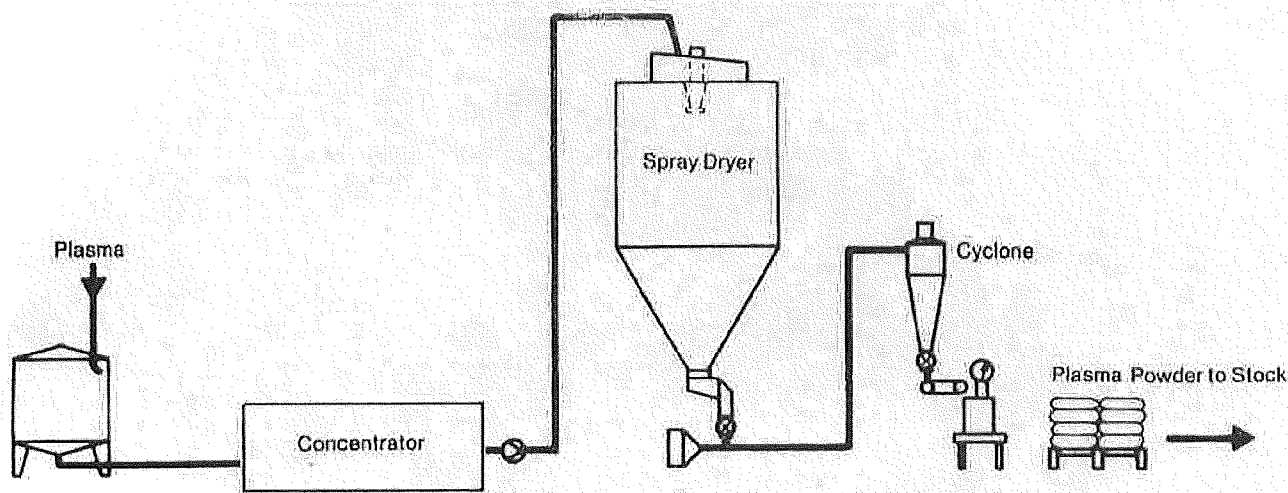
- x) Falling-film 28 %
RTC 35 %.

Powder is hygroscopic, and will absorb up to 10 % water. Air-tight packing is essential for maintaining good solubility even though shelf-life still acts to reduce solubility. Typically, solubility will decrease 0.5-1 % during each month of storage.

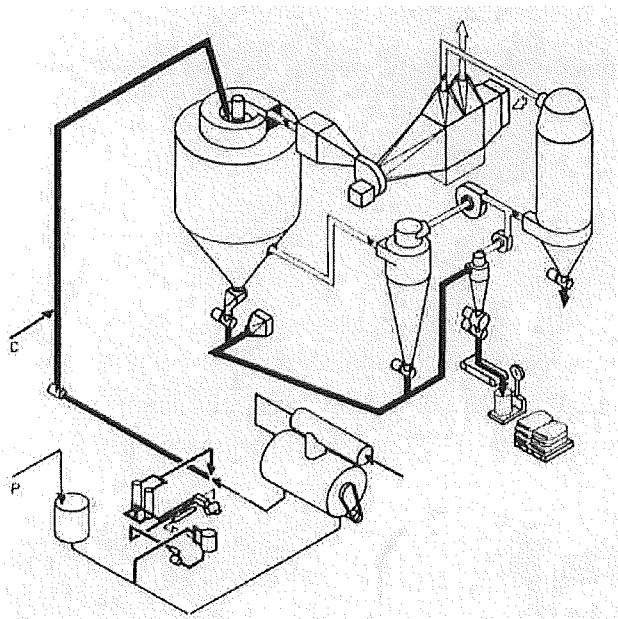
The red cells from the separator, concentrated plasma and decoloured, concentrated cellular fraction can be pumped directly to the spray drying installation for atomisation and low temperature drying. From the base of the drying chamber and cyclones, powder is conveyed pneumatically to a bagging-off cyclone. The final powder contains from 93% to 97% total solids and is therefore stable during storage.

The proteins and special water-binding properties of the plasma are protected throughout the process.

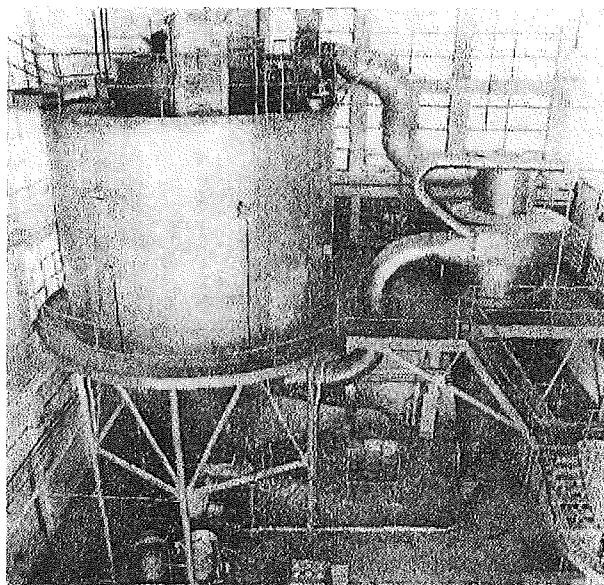
The powder is 100% resolvable. This requires that the powder temperature does not exceed 60°C during drying, since at higher temperatures the proteins become insoluble. The water content in the finished product must be under 10% when producing long shelf-life plasma powder.



Concentration and Spray Drying.

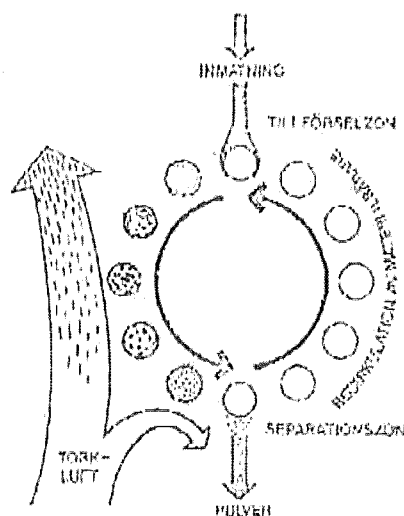


Spray Drying.

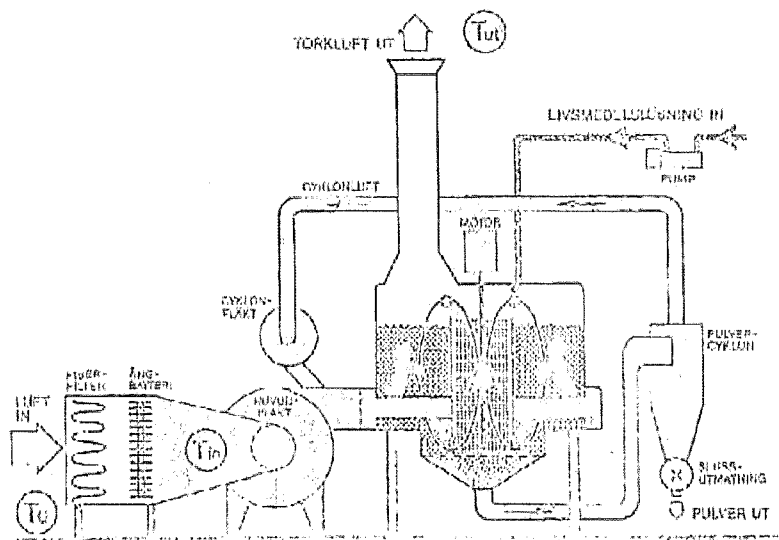


Spray dryer installation.

5.4 Ball Drying.



Principe of the ball circulation



Ball dryer system type ECAL

Tørningsprocessen foregår i et tørrekammer, som er delvis fyldt med kugler bestående af Polycarbonat (FDA godkendt).

Kuglerne omrores i lodret retning, og i øverste del indmættes kuglerne med flydende plasma.

Under kuglernes transport ned igennem tørreren, tørres de indmættede kugler af modstrømmende luft ved en indgangstemperatur på 86 - 92°C og returneres derefter igen til den øverste del af tørreren til ny indmætning.

Opholdstid i torrekammer i strømmende luft er ca. 45 min. Afgangstemperaturen på pulveret er 66 °C. Tiden og temperaturen er fastsat ud fra hensyn til produktets funktionelle egenskaber, idet højere temperaturer vil ødelægge produktets funktionalitet.

6. Commercial applications of blood products

Many different applications are described in the technical press and in patents. Only the main applications are described here.

6.1 Whole blood

Whole blood can be spray dried following an up concentration from 20% to approx. 35% dried matter. When blood is for human consumption, the temperature of the finished product is held below 80°C. If dried blood is subjected to higher temperatures, it will not be 100% resolvable and therefore have a lower commercial value.

6.2 Whole blood and blood powder

The uses of whole blood in foods-buffs for human consumption are limited due to its strong red colour. It is mainly applied to black pudding and the like, where it is used in its natural or dried form. It can also be used as a binder in meat emulsions, and together with skimmed milk powder is used in pulp, soup, pat§ and fish products. Furthermore it can be applied in diet food due to its ease

of digestibility.

Dried blood has a colour in the scale from black to dark red. Final colour depends upon how drying is conducted.

Blood can also be used both in the baking industry for iron enrichment of bread and in many medical prescriptions.

6.3 Plasma

Plasma finds greater commercial use than whole blood, because there are no problems with colour or changes in taste. Plasma has also unique gelatination and binding effects. The amino acid and isolated lysine compositions are also in better balance.

In fine cut meat products, the addition of plasma reduces the cooking loss and minimizes separation. Up to 3% plasma in dried form or the corresponding quantity in liquid form when added to Frankfurter, salami or other products, gives good results.

In other fields - both within and outside the meat industry - there are many potential applications for plasma. 10% of the flour in bread can be replaced by dried plasma, and this increases the nutritive value of the bread. When mixed with Soya, it can replace eggs in luxury bread, cakes and biscuits, and it can replace sweet oil/water emulsions in the production of milk substitutes and in margarine. It can act as a substitute for eggs in ice cream, cakes and meringues. It has even been used as a fining substance in wine production.

6.4 Red cell fraction

The red cell fraction is not as useable as plasma, but it can be added directly in black pudding and similar products. It also finds application in pet food and animal fodder,

Globin from the red cell fraction is a good emulsifier, stabilizer, and has good raising power. Applications are similar to those of plasma. (Plasma contains after separation fibrinogen and the greater part of the albumin).

6.4.1 Nutritional Properties

As isoleucine is practically absent in haemoglobin and in the hydrolysed blood cell fraction, these proteins are insufficient in nutritive value when used as a sole source of protein for human beings.

However, when combined with meat, e.g. by incorporation into meat pieces, an adequate nutrient with regard to amino acid profile is obtained in most practical cases.

7. Use of products

Biological values of some food proteins in the formation of plasma proteins (dogs).

(Values represent grams of plasma protein formed per 100 g of food protein as supplement to a basic adequate diet).

Food Protein	Plasma Protein Formation, g	
Serum, beef	38	100 %
Yeast, fresh, autoclaved	23	61 %
Kidney, pork, cooked	22	58 %
Rice, polished	19	50 %
Lacteal albumin	18	47 %
Skeletal muscle, beef	18	47 %
Egg white	17	45 %
Irish potato, powdered	16	42 %
Liver, pork, raw or cooked	15	39 %
Soybean	14	37
Heart, beef	13	34 %
Casein	12	32 %
Red blood cells, dog	10	26 %
Brain, pork	8	21 %
Stomach, beef	7	18 %
Zein (from corn)	0	0 %

Ovalbumin and ovoglobulin are proteins found in the white of egg, and in the yolk, phosphoprotein ovovitellin. Together these proteins offer an excellent supply of all the essential amino acids for growth, healing and reproduction in animals and as far as we know for human being as well.

7.1 Uses of plasma

Flake ice frozen plasma: App. 7 % protein

Apply: 1) Secondary materials in meat and minced meat (sausages).
2) Meat/water substitution in minced meat (sausages),

Ex.: 1) Reduction of boiling waste in picnics (sausages) (2-4 %). Added to the normal minced meat (10-20%).
2) Substitution of meat/water in proportion 1:2 or 2:5.

Plasma concentrated by reverse osmosis (RO): Ca. 17 % protein

Apply: 1) Meat substitution in meat and minced meat (sausages).
2) Egg albumin substitution in bakery.

Ex.: 1) Substitution of 1/3 binding meat in minced meat (sausages) (10 %).

Plasma spray dried: App. 70% protein. Rehydrated in proportion 1:3 => 17½ % protein.

Apply: 1) Meat substitution in minced meat (sausages).

Ex.: 1) Substitution of 40% binding meat.

Cooking loss tests with dried blood plasma added to sausages			
	Cooking loss %		
	Water	Fat	Total
Control sample (65% meat)	6,4	9,9	16,3
+3% Soya isolate	4,8	7,1	11,9
+1% dried blood plasma	5,2	6,7	11,9
+2% dried blood plasma	5,1	7,1	12,2
1% dried blood plasma instead of 4% lean meat	5,8	6,7	12,5
2% dried blood plasma instead of 8% lean meat	4,4	3,9	8,3

7.2 Uses of corpuscles.

Refrigerated corpuscles: app. 35% protein

Apply: 1) Black pudding
2) Colouring of meat
3) Medical drugs

Ex.: 1) Colouring of light, meat and sausages
2) Colouring of bread

Corpuscles spray dried: ca. 90% protein Apply: As for refrigerated corpuscles

Decolourised and spray dried corpuscles:

Hem deal: red Apply: 1) Colouring
2) Iron contribution

Globin deal: white 90% protein
Apply: 1) Secondary materials in meat and sausages
2) Protein contribution

7.3 Functional properties of blood proteins.

Functional properties of blood proteins		
	Plasma	Globin
Solubility	good	good below pH6
Swelling with water	good	very good
Emulsifying capacity	fair	good
Emulsion stability	good	good below pH6
Emulsion stability	poorer with salt	better with salt
Foaming	good	very good
Gel formation	very good	none (cream)

7.4 Protein content in secondary materials.

Protein content in secondary materials	%
Soya - bits	50
Soya - concentrate	70
Soya - isolate	90
Casinate	90
Whey - isolate	90
Plasma - liquid	7
Plasma - concentrate	17
Plasma - powder	70
Plasma powder mixed wither hydrated globin powder (1:3)	17

8. General Information.

Amount of blood per kg living weight			
	Volume ml/kg	V/W in % of weight	Practicable amount to collect in % of weight
Horse	75 - 90	7,5 - 9,0	
Cattle	64 - 82	6,4 - 8,2	3 - 4
Calf	58	5,8	5 - 6
Sheep	80	8,0	4 - 4,5
Lamb	60 - 70	6,0 - 7,0	3,5 - 4
Pigs	74	7,4	3 - 4
Chicken			

Young animals have smaller amount of blood per kg living weight.

Suckling animals have greater amount of blood per kg living weight.

Amount of Collected Blood

100 kg blood = The amount of blood collected from 40 pigs or 7 cattle.					
55 kg water	1 kg salt	18 kg protein	1 kg salt	25 kg water	
60 kg plasma			40 kg Red cells		
55 kg water	1 kg salt	4 kg protein	14 kg protein	1 kg salt	25 kg water

6,67 % protein / kg plasma ←

→ 35 % protein / kg Red cells

From 100 kg blood there can be made the following dried products:

Plasma: 5,4 kg 93% solids content

Red cell: 16,2 kg 93% solids content

100 pigs give: 250 kg blood

- 150 kg plasma 8,33% solids
= 13,5 kg plasma powder 93% solids
- 100 kg Red cells 37,5% solids
= 40,5 kg Blood cell powder 93% solids

100 cattle give: 1500 kg blood

- 900 kg plasma 8,33% solids
= 81 kg plasma powder 93% solids
- 600 kg Red cells 37,5% solids
= 243 kg Blood cell powder 93% solids

Distribution of blood in different parts of the body	
Heart	5 %
Pulmonary vein	25 %
Artery	12 %
Capillary	6 %
Vein	40 %
In Reserve	12 %

Comparison between blood and milk			
		Blood (Pigs)	Milk
Protein	%	18,9	3,5
Fat	%	0,4	3,9
Carbon hydrate	%	0,1	4,9
Water	%	79,1	87,0
Minerals and other	%	1,4	0,7

9. Physical Properties.

Blood has a specific gravity of approx. 1,055, i.e. a little higher than water, but its precise value depends upon the blood corpuscles and plasma contents. Its osmotic pressure is approx. 7 atm. which corresponds to the osmotic pressure of a 0.9% sodium chloride solution. This means a freezing point depression of 0,56 °C and an osmotic concentration of approx. 0.3 (7:22.4).

Blood is faintly alkaline with a pH of approx. 7.4.

Specific gravity, viscosity and pH of blood			
	Gravity g/ml	Viscosity cp (mPa*s)	pH
Horse	1,053 (1,046 - 1,059)		7,2 – 7,55
Cattle	1,052 (1,046 - 1,058)		7,35 – 7,5
Sheep	1,051 (1,041 - 1,061)		
Pigs	1,051 (1,039 - 1,064)	152	7,32 – 7,68
Pigs Haemoglobin	1,074	1330	
Pigs Plasma	1,033	14	
Pigs Plasma 6,5 % protein	1,014		
Pigs Plasma 13 % protein	1,047		
Pigs Plasma 18 % protein	1,046		

Specific Heat, Freezing point and Osmotic pressure			
The specific heat for blood corresponds to an 18% protein solution.			
Relation between protein content and specific heat:		Blood	0,87 cal/g
		Plasma	0,94 cal/g
		Corpuscles	0,77 cal/g
Freezing point °C	Cattle -0,585	Sheep -0,619	Pigs -0,615
The osmotic pressure corresponds to a 0.9% NaCl solution (0.154 M).			

Composition of blood from different animals					
Total per 100 ml		Horse	Cattle	Sheep	Pigs
Water	g	78	80	81	80
Total protein (6,25 N)	g	17 – 18	18 – 19	18 – 19	18 – 20
Haemoglobin	g	11	12	12,5	12 – 13,5
Glucose	mg	55 – 95	40 - 60	30 - 60	60 – 90
Sodium	mg	200	260	280	215
Potassium	mg	170	40	35	170
Calcium	mg	4	7	5	5
Magnesium	mg	4	5	3	3,5
Iron	mg	58	40	34	42
Chloride	mg	280	310	310	300
Phosphate total	mg	27	18	17	41
Inorganic	mg	3	4	4	5
Lactate	mg	14	12	10	5
Composition of animal blood (weight per cent)					

Component in %	Cattle			Sheep			Pigs		
	Blood	Plasma	Corpuscles	Blood	Plasma	Corpuscles	Blood	Plasma	Corpuscles
Water	80,9	91,3	60,5	82,2	91,7	61,5	79,1	91,8	62,5
Haemoglobin	10,3		31,7	9,6		31,8	14,2		32,7
Protein	7,0	7,1	5,5	6,5	6,8	5,8	4,7	6,8	1,9
Sugar	0,007	0,11		0,07	0,11		0,07	0,12	
Cholesterol	0,11	0,11	0,26	0,16	0,11	0,3	0,04	0,04	0,5
Lecithin	0,23	0,18	0,33	0,23	0,17	0,35	0,23	0,14	0,37
Fat	0,15	0,22		0,09	0,13		0,11	0,20	
Sodium	0,21	0,25	0,14	0,21	0,25	0,13	0,14	0,24	
Potassium	0,03	0,02	0,05	0,03	0,02	0,05	0,16	0,02	0,34
Iron	0,02		0,06	0,02		0,06	0,02		0,06
Calcium	0,01	0,01		0,01	0,01		0,01	0,01	
Magnesium	0,004	0,004	0,002	0,003	0,004	0,002	0,008	0,004	0,002
Chlorine	0,31	0,37	0,18	0,31	0,37	0,17	0,27	0,37	0,15
Phosphoric acid	0,04	0,02	0,07	0,04	0,02	0,2	0,10	0,02	0,08

Essential amino acid composition in cattle beef and cattle blood as % of total protein.				
	Beef	Whole blood	Plasma	Corpuscles
Lysine	8,4	9,4	8,3	10,3
Tryptophane	1,1	1,4	1,7	1,3
Threonine	4,0	4,7	7,1	4,1
Valine	5,7	8,0	7,4	9,6
Metionine	2,3	1,8	1,3	1,5
Isoleucine	5,1	0,4	3,4	0,3
Leucine	8,4	13,6	10,1	13,4
Phenylalanine	4,0	8,0	5,7	8,0

The chemical composition of plasma per 100 ml

Total per 100 ml		Horse	Cattle	Sheep	Pigs
Water	g	90	91	91	91
Total protein (6,25 N)	g	6,8 – 8,4	6,7 – 7,8	6,5 – 6,8	6,5 – 7,5
Fibrinogen	mg	300	600	360	500
Residue N	mg	34	31	38	32
Bilirubin	mg	1,1	0,2	0,2	0,2
Sodium	mg	320	325	330	335
Potassium	mg	18	17	18	20
Calcium	mg	10	10	10	10
Magnesium	mg	2,8	3,0	2,5	3,0
Iron	μg	125	100	120	180
Chloride	mg	360	370	370	370
Cu	μg	130	85	80	220

Distribution of plasma in % of total protein				
	Horse	Cattle	Sheep	Pigs
Albumin	40	44	42	45
Globulin	16	14	18	17
Globulin	23	11	9	18
Globulin	21	31	31	20

Amino acid composition in blood serum and fibrinogen					
Amino acid mg/100 mg	Serum Protein total	Serum Albumin	Serum Globulin	Fibrinogen WHO	Egg WHO
Valine	6,1	6,8	8,8	5,1	7,4
Leucine	13,8	11,5	9,2	8,9	9,4
Isoleucine	2,9	2,4	2,6	4,3	6,9
Serine	3,4	4,5	10,4	12,8	7,8
Threonine	5,3	5,7	7,4	7,3	5,0
Lysine	8,0	11,3	7,6	8,2	6,9
Phenylalanine	5,4	6,9	5,1	4,0	5,8
Tryptophane	1,5	0,6	2,9	2,4	1,6
Metionine	1,7	1,3	1,1	2,3	3,3
Cystine	3,9	6,0	2,6	2,3	2,3
Chemical score %	42	35	33	62	100

From the table we have:

- 1) That the first restricted amino acid in all 4 fractions is isoleucine.
- 2) Serum protein has a low content of methionin, which the high cystine content

compensates for. Tryptophan and lysine content and the aromatic amino acid are sufficiently large.

- 3) Serum albumin has a low tryptophane content, which is not the case in serum and plasma. The sulphur content and the aromatic amino acid are rather large.
- 4) Gammaglobuline has a nutritional good composition. The isoleucine content is too small.
- 5) Fibrinogen has in comparison with other plasma proteins a large content of isoleucine, which gives plasma a chemical score of 44 % against the serums 42 %, because 8-10 % of the plasma protein is fibrinogen.

Dried blood composition after drying at low temperature					
		Whole blood	Blood albumin	Plasma	Corpuscles
Water	%	7	7	7	9
Protein (6,25 N)	%	89	91	72	86
Fat	%	1	1	1	1
Ashes	%	5	3	12	6
Nitrogen solubility Index (N.S.I.)		91	91	83	12

Typical analysis of Amino acid composition in spray dried plasma powder			
Alamine	6	Leucine	10,5
Aspargin acid	10,5	Lysine	9,3
Arginine	5	Metionine	1
Cystine	1,2	Proline	5
Fenglalalin	5,4	Senine	5,5
Glycine	3,8	Threonine	6,3
Glutamine acid	12	Tryptophan	0,8
Histidine	5	Tyrosine	3,7
Isoleucine	3	Valine	7

Colour: White to light yellow
 Flavour and smell: Neutral
 Water absorbility: 14-16 multiply powder weight
 Water solubility: 100% when it's dried by low temperature
 Bacteriological standard: Total germ max 10^6 , coli max 10^3
 PH: app. 7.5-8.5 in water dissolution
 Bulk density: 650-700 g/litter
 Protein: app. 74 %
 Salt: app. 20 %
 Water: app. 5-7 %
 Fat: app. 1-2 %

Typical analysis of Amino acid composition in spray dried corpuscles (haemoglobin) powder			
Alamine	8,5	Leucine	13,1
Asparagin acid	11,4	Lysine	8,8
Arginine	4,1	Metionine	0,8
Cystine	0,7	Proline	3,2
Fenglalalin	6,9	Senine	4,2
Glycine	4,6	Threonine	3,4
Glutamine acid	8,4	Tryptophan	1,2
Histidine	7,1	Tyrosine	2,2
Isoleucine	0,6	Valine	9,5

Colour: Brown to red brown. By heating black to brown

Flavour and smell: As blood

Water absorbility: 5-7 multiply powder weight

Water solubility: 100% when it's dried by low temperature

Bacteriological standard: Total germ max. 10^6 , coli max 10^3

PH: app. 6.7-7.2 in water dissolution

Bulk density: 500 g/litter

Protein: app. 90 %

Salts: app. 2 %

Water: app. 7 %

Iron: app. 0.25 %

Calcium: app. 0.04 %