RESEARCH IN IMPROVING THE WHC (WATER HOLDING CAPACITY) OF MEAT IN SAUSAGE PRODUCTS

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INTRODUCTION

In the process of making sausage products, the cooking yield and quality of sausage products are directly affected by water holding capacity (WHC) of ground meat. WHC of meat is the holding capacity of water content in raw meat plus the water added to meat. WHC of meat is directly connected with the texture, tenderness, slicing, elasticity and taste of sausage pro-ducts. Therefore, it is noted by the experts all over the world on how to best preserve the water of ground meat and the added water during the processing very well.

WHC of sausage products is affected by a lot of factors, such as the water holding capacity of raw meat itself, and the technical conditions during the processing.

The water content in muscle tissue of all kind of animal meat is around 70-75%. Of all the water, 70% is in myofibrils and 20% in sarcoplasm, the last 10% water is in connective tissue. The water exists in three forms: one is free water which can flow freely and stays in the muscle fibers and fiber gaps. The second form is in myofibrils. Due to the special structure of myofibrils, the water of form is difficult to leak out. The last one is bound water which is a thin water film. The water film is formed by the electrostatic gravitational force among the molecular and polar groups around the protein of muscles.

The water lost and preserved during the processing is mainly the water that does not flow easily. The formation of the water of this type is closely related with the network of muscle protein. If the electrostatic gravitational force among protein molecular is enhanced, the water in protein structure will be forced out of the network, just like the water goes out from a sponge. The WHC of meat will reduce. If the electrostatic repulsive force among protein molecules is increased, the expansion will appear in the net structure of protein, the volume of protein will be enhanced, and WHC value of meat will be raised too.

In the process of making sausage products, the protein in the sausage will be denatured by heating, and the polar radical in the protein molecular chain will backturn to its inner, and the electrostatic repulsive force will be reduced, the muscles will shrink automatically, thus the volume of muscle becomes less, much meat juice is forced out of muscles, consequently, WHC of meat is reduced.

The objective of this research is to study the processing properties and WHC of ground meat. According to China Food Sanitary Regulation, if acid, alkali, polyphosphate, sodium chloride and isolated soybean protein are added to the ground meat, the properties and WHC of ground meat in the processing will be improved. The desirable charge ratio of sausage products is concluded to improve WHC of ground meat. It plays an important role in the practice, and enhances the cooking yield and the quality of sausage products.

MATERIALS AND METHODS

(A) Experiment material:

1. Raw meat material: frozen & cut meat which has been removed from all trimmable fat and connective tissue.

2. Additive:
(1) Sodium pyrophosphate ($Na_4P_2O_7$):analytically pure (a.p), provided by Beijing Red Star Chemical Plant
(2) Sodium tri-polyphosphate ($Na_5P_3O_{10}$): chemically pure (c.p), provide by Beijing Red Star Chemical Plant
(3) Sodium hexametaphosphate $(NaPO_3)_6$: chemically pure, provided by Tian Jin Chemical Agent Plant
(4) Sodium chloride: edible salt

(5) Isolated soybean protein: contain over 90% protein, provided by Ji Lin Qian Guo Qi Protein Factory

(B) Experimental instruments

1. Grinder: plate 0.32cm

2. High speed centrifuge: Model LG-2.4, maximum rotation rate is 10,000 rpm., centrifuge tube: 6X40ml, Beijing Medical Centrifuge Factory

3. Microwave oven: Model ER-692, power consumption: 1250 W, microwave output: 650 W, microwave frequency: 2450 Hz, made by China Electronic Instrument Industry Company 778 Factory

4. Pressure gage for measuring WHC of meat pressure: 0 - 35 Kg/cm^2, made by Heilongjiang Commercial College

5. Analytical balance
Maximum load: 150 g, made by Xiang Yi Balance Instrument Factory

6. Planimeter: Model DQJI, made by Shanghai Nautical Instrument Factory

(C) Experiment Methods

1. Sample preparation
Lean muscles which had been removed all trimmable fat and the connective tissue is ground. The chemical agents are dissolved in distilled water which weighs at 5% of meat, it is then mixed and put in 0-4°C for 30 minutes, then WHC of meat are tested by pressing technique, cooked-centrifuge technique, and microwave oven heating method.

2. Pressing method
Approximately a 0.5g meat sample is placed on filter paper with a 9cm diameter. It is pressed for 1 min. at 35Kg/cm^2 by a pressure gage. The areas are measured by a planimeter and the percentage of free water is calculated by the following equation:

$$B=(1-F)=1-\frac{a-b}{M}\times 61.10$$

B: % Bound water
F: % Free water
a: wet area (mm^2)
b: meat film area (mm^2)
61.10: the water which filter paper can get in a unit area.
M: total water content in the sample meat

3. Cooked-centrifuge technique
Approximately a 10g meat sample was placed in a glass beaker and the beaker was heated at 90°C for 10 min. in water bath. After heating, the meat sample was carefully removed from the tube with the aid of forceps. When it cooled at room temperature, it was wrapped in cotton clothing and placed into a stainless steel centrifuge tube with enough absorbent cotton on the bottom. The samples are centrifuged for 10 min. at 10,000 rpm, then the samples in the tubes are weighed. The WHC value are calculated by the following equation:

$$WHC = (1-\frac{T}{M})X100 = (1-\frac{B-A}{M})X100$$

WHC --- water holding Capacity
T --- total juice loss during heating & centrif.
B --- wt of sample before heating
A --- wt of sample after heating and centrifuge.
M --- Total water content in sample meat.

4.Microwave oven heating method
100g meat samples are employed and placed into petric dish (100X15mm) cover and pressed with 5 bl. for 1 minute. The pressure was removed, and the meat samples were then put into the microwave oven, heating it for two minutes. The internal temperature of the products went up to 76-80°C. Heated products were separated from the petric dish cover and drained for 5 minutes with a funnel, after that it was weighed immediately, The cooking yield is calculated by the following equation:

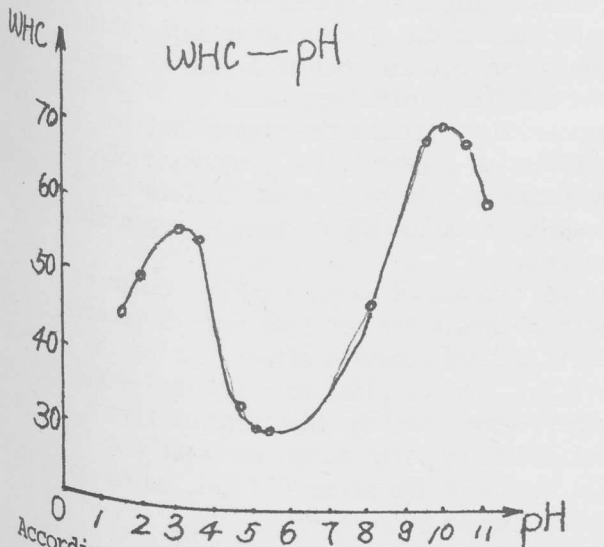
$$Y = \frac{W_2 - W_1}{W_1 - W}\times 100\%$$

Y: % cooking yield
W : weight of petric dish
W_1: total weight of meat samples and petric dish before heating (g)
W_2: total wt of meat samples and petric dish after heating (g)

RESULTS AND DISCUSSION

(A) Effects of ground meat PH value on WHC of meat

The PH value of meat will not stop changing until the processing ends. Citric acid and sodium carbonate were employed in ground meat for changing PH value of the meat. The cooked centrifuge method was used to test WHC of meat at different PH value. The relation between PH value and WHC of meat was shown in the following figure(1);



According to the above figure, the WHC of meat was lowest when the PH value is at 5.2. This is due to the isoelectric point of muscle protein whose PH value was at 5.2 also. This agrees with the phenomenon of postmortem that happened at isoelectric point. When the PH value is changing from 3.5 - 10, it is drifted off from PH value at 5.2, WHC of ground meat is known to be significantly improved, the reason is that the main structure of meat is protein structure, and the amino acid molecular in protein laid in zwitterion $^{+}H_3N\text{-}R\text{-}COO^{-}$ when acid or alkali was added;

When acid is added:

$$^{+}H_3N\text{-}R\text{-}COO^{-} + H^{+}A \rightarrow {}^{+}H_3N\text{-}R\text{-}COOH + A;$$

When alkali is added,

$$^{+}H_3N\text{-}R\text{-}COO^{-} + B \rightarrow H_2N\text{-}R\text{-}COO^{-} + H^{+}B$$

But the molecular of protein is present as complex cations in acid media, as complex anions is alkali media and as zwitterions in isoelectric point of protein.

$$\underset{\text{(complex cation)}}{\text{protein}^{+}} \overset{OH^{-}}{\underset{H^{+}}{\rightleftharpoons}} \underset{\text{(zwitterion)}}{\text{protein}} \overset{OH^{-}}{\underset{H^{+}}{=\!=}} \underset{\text{(complex anion)}}{\text{protein}^{-}}$$

The amount of electric in protein molecular was enhanced by adding acid or alkali, and the protein chain has the same amount of electric, repulsive phenomena emerge. The distance among the chains of protein are enlarged, the structure of protein was relaxed, and water molecular goes into the gap of protein. The WHC is thus increased. WHC of ground meat would decrease as changing acidity and alkali (PH<3, PH>10). Because excessive acidity or alkali would cause denaturation of meat protein and result in changes of the groups in actin and myosin peptide chains. The chemical bond which was formed by the electrostatic action of some negative charge group necessary to support three-dimensional structure was destroyed. In the meanwhile, polar radical in the actin and myosin was hidden due to the denaturation action of acid and alkali. When the electrostatic repulsive forces were reduced, WHC of ground meat would be largely decreased.

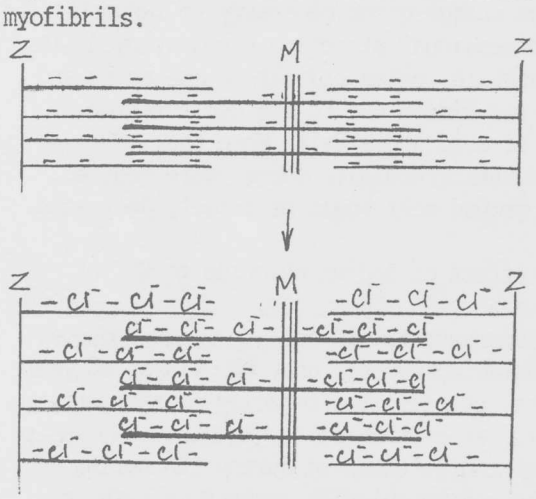
(B)The effect of sodium chloride to WHC of ground meat

It is necessary to add salt to meat products. This would improve not only the flavor of meat products, but also the capacity of antiseptic. Moreover, at certain salt concentration, WHC of raw meat can be enhanced during the curing. When the sodium chloride content is between 4.6-5.8%, the ground meat has a maximum WHC value. In the common process of making sausage, 3% of sodium chloride was added according to consumer need. In the experiment, 1%, 2%, 3% sodium chloride was added respectively, and WHC of meat is shown in the following table;

No. of treatment	NaCl%	Press Tech. (%,B.W) (mean±SD)	Centrifuge (mean±SD)	Micro-wave oven heating (mean±SD)
1	0	53.64±1.20	25.48±0.91	67.00±0.40
2	1	64.23±1.89	29.33±0.55	76.99±0.41
3	2	80.62±1.37	44.25±0.68	87.05±0.11
4	3	89.31±1.84	45.27±0.54	87.49±0.41

According to the table, WHC of meat is enhanced as the amount of sodium chloride increases. WHC is increased by 35% by using pressing method, 20% by using microwave oven heating method and cooked centrifuge method. The result proved that sodium chloride has important effect on the WHC of meat.

The reason why NaCl can increase WHC of meat was that NaCl could affect the muscle fibers expansion, the expansion of muscle fibers is due to the presence of high concentration of sodium chloride, there were many chloride ions bound in the fibre. The increase of negative electric charge results in the increase of electrostatic repulsive force and this would enhance the myofibrils expansion, and WHC of ground meat goes up. Sodium acetate could not cause the expansion of myofibrils, we infer it is chloride ions that are bound in myofibrils, rather than the sodium ions. The following figure shows that chloride ions are bound in myofibrils.



Another possible function of edible salt is that NaCl destroys the crosswise chain structure which prevents the expansion of myofibrils. The high level of NaCl could cause the electrolysis of protein molecular group. These crosswise chain structures represents the M-line, Z-line and bound cross-bridge that prevent the expansion in myofibrils of these structure, the myofibrils expanding would go on smoothly.

We could also explain the reasons why NaCl can enhance WHC of ground meat by using the changing protein from gel state to colloidal state after curing with NaCl.

The protein without curing ground meat is in nonsoluble state or gel state. After curing by the adaptable ion strength action, the nonsoluble protein is turned into soluble one, In other words, the extraction of myosin during curing meat is the main reason that WHC of ground meat is increased.

The myosin which is in gel could absorb water to expand, myosin itself had a certain WHC, but the absorbent expansion which was formed by solvation was limited. That is to say, without enough ion strength myosin, the myosin couldn't absorb infinite water to expand from colloidal sols. Therefore, WHC was limited in a small range. In the process of heating, the non-polar radical which had been hidden in the side structure of protein was exposed due to the denaturation. The appearance of oil non-polar radical created the environment of repulsive water, and WHC of ground meat was greatly reduced. That's why non-curing meat lost much water during the process of sausage making. Due to curing, the colloidal sols of myosin changed from limited expansion to unlimited expansion to realize the high solvation. In certain ion strength, the processing of solvation should be done as complete as possible to allow WHC of meat to reach its maximum.

In the process of sausage making, colloidal sols of myosin was set free from the muscle cell, and had adhesive effect. During the heating, the colloidal sols absorbed sufficient water. After cooling, meat product formed great gel enclosing large amount of water and fat in the inside of the network of gel, so as to meet water-keeping purpose.

(C) The effects of polyphosphate

Recently, the meat researchers found that phosphate, especially different kind of polyphosphate played active role in improving WHC of ground meat. Polyphosphate could accelerate WHC of NaCl, that is to say, polyphosphate and sodium chloride possess a coordination function on improving the WHC of ground meat. It is reported that polyphosphate could increase WHC by 10%-15%. The mixed use of polyphosphate and sodium chloride increased the WHC by another 10% more than using NaCl only. $Na_5P_3O_{10}$ was allowed to use maximum amount 2g/Kg, and $Na_4P_2O_7$ 1g/Kg. $(NaPO_3)_6$ 1g/Kg, by China Food Sanitary Regulation. During the experiment, the amount of polyphosphate was added according to the regulation, and WHC of the ground meat was tested.

The WHC of $Na_5P_3O_{10}$

No.	$Na_5P_3O_{10}$ (g/kg)	Centrif.tech (mean±S.D)	Microwave oven heating (mean±S.D)
1.	0.45	28.77±0.75	71.92±1.21
2.	0.83	29.30±0.20	73.06±0.07
3.	1.33	31.64±0.97	74.12±0.33
4.	2.00	32.54±0.10	75.21±0.36

Note:the value of above table is the average and standard deviation of three in four parallel tests of the samples

The WHC of $Na_4P_2O_7$

No.	$Na_4P_2O_7$ (g/Kg)	Centrif. tech (mean±S.D)	Microwave oven heating (mean±S.D)
1.	0.22	32.13±0.74	72.92±0.42
2.	0.45	32.68±0.60	75.40±0.12
3.	0.67	32.08±0.32	76.43±0.21
4.	0.89	31.97±0.42	76.61±1.21
5.	1.00	35.54±1.29	76.58±1.26

Note: the value of table is the average and standard deviation of three in four parallel tests of the samples.

WHC of $(NaPO_3)_6$

No.	$(NaPO_3)_6$ (g/Kg)	Centrif. tech (mean±S.D)	Microwave oven heating (mean±S.D)
1.	0.22	26.68±0.40	72.63±0.50
2.	0.45	28.74±0.52	73.63±0.72
3.	0.57	26.98±0.11	74.48±0.91
4.	0.67	28.27±0.59	74.96±0.32
5.	0.89	28.64±0.92	74.92±0.60
6.	1.00	28.58±0.32	75.58±1.43

Note: the value of table is the average and standard deviation of three in four parallel tests of the samples.

Usually, WHC of meat could be enhanced by 8-10% from adding sodium tri-polyphosphate, 10% by $Na_4P_2O_7$, 4-8% by $(NaPO_3)_6$. According to the data given in the above tables, WHC of meat is remarkably enhanced as the amount of polyphosphate increases and the effect of sodium hexametaphosphate to WHC of meat is subordinate to the other two polyphosphates. We suppose its dissolution in the water is very low.

WHC of meat which was enhanced by polyphosphate may be related to the properties of polyphosphate.

Polyphosphate produces a buffer effect, which leads to meat PH moving away from isoelectric point. Any minor change of PH which was away from isoelectric point would cause the myofibrils to expand, and change WHC of meat. Polyphosphate had the properties of sequesting metal ions. Ca^{2+} and Mg^{2+} which was bound firmly in myofibrils were sequested with polyphosphate. And the carboxy was set free from meat protein. Therefore it enhanced the electrostatic repulsive force and lead to expand three-dimensional network in protein structure, thus loosen the three-dimensional network of protein structure, and water moleculars become adherent at the network. Pyrophosphate and tri-polyphosphate had the special usage to the electrolysis actomyosin of muscle protein. The actomysin which was formed during postmorten was electrolysized to be actin and myosin, the original network got back. The water molecular went into the network again, so that WHC was enhanced, at the same time myosin dissolved in heating duration to form great gel, to keep large amount water moleculars.

Polyphosphate could enhance ionic strength. In certain range of ionic strength, the ground meat became colloidal sols as the dissolved myosin increased. As polyphosphate was added into ground meat in the processing, it helped the myosin turn into colloidal sols so as to increase WHC of meat.

The heating denature of myosin was prevented by polyphosphate added, so did WHC of meat.

(D) Application of myosin isolate protein (ISP)

ISP is a functional soybean protein. It contained over 90% protein, and had very strong functionality, such as emulsion, holding water, adhesion. ISP could absorb as much as three to four time of water.

WHC of ISP

Addition (%)	Press Tech. (mean±S.D)	Centrif. Tech. (mean ± S.D)	Microwave oven heating (mean±S.D)
0.	69.63±1.87	17.22±0.72	68.4 0±0.20
3.	74.44±1.25	21.64±0.79	70.8 0±0.50
5.	79.81±1.94	27.42±1.28	72.9 0±0.40

According to the data of above table, WHC of meat was enhanced as the amount of ISP increased. But addition usually is controlled below 5% for soya odor consideration.

(E) Application

According to the above results, 0.4% of polyphosphate and 5% ISP were added to Harbin Red Sausage (H. R. S.) for the practical experiment.

H. R. S. contained mainly lean pork meat, pork fat, starch, garlic and other seasonings. H.R. S. undergoes several processing procedures: cured ground, injected, baking, cooked, and smoked. It was an enjoyable meat product in northern China.

	Moisture (%)	cooking yield (%)	Color	Odor
Added Polyphosphate and ISP	36.61	109.73	dark red	no soya odor
blank	26.74	91.33	dark red	normal

Concluding from the experiment, generally, the meat product output could be increased by 15-20% or so, and the quality of meat products are improved significantly. It has attained remarkable economic benefit.

CONCLUSION

A. WHC of meat could be remarkably enhanced by changing the PH value of ground meat, especially in Chinese cooking, the tenderness of meat could be improved after the aged beef and chicken were treated by adding alkali and acid, aged meat become easy to cook.

B. WHC of meat increases by adding sodium chloride, but it required a certain amount of NaCl. However, NaCl in products could be kept as low as 3% of meat by adding phosphates as much NaCl being added to meat during curing.

C. WHC of ground meat could be increased by sodium tri-polyphosphate, pyrophosphate and hexametaphosphate. This technique can be widely applied to production of meat products.

D. The output would be enhanced by 15-20% when NaCl, polyphosphate and ISP were added to the ground meat products. And the quality of meat was remarkably improved. The level of protein in sausage was increased as well.

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