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Sauce Separation in Cream Stew during Vacuum Cooking

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The cause of sauce separation in cream stew was investigated when a mixture of 16.6 g of white sauce, 40 g of chicken thigh meat, and 33.4 g of bouillon soup was cooked under a vacuum. The sauce in the cream stew separated irrespective of the evacuation procedure during 60 min of cooking at 90℃, but this separation did not occur in a cream stew without the chicken thigh meat. The amount of protein eluted from the chicken thigh meat during cooking increased with increasing cooking time, reaching about 300 mg after cooking. The addition of 200 mg or more of bovine serum albumin or ovalbumin instead of chicken thigh meat also caused the sauce in the cream stew to separate.

These results suggest the sauce separation in the cream stew during vacuum cooking depended not on the evacuation procedure but on the sarcoplasmic protein eluted from the meat during cooking.

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Keywords: vacuum cooking, white sauce, separation, soluble protein, micelle, cream stew.

INTRODUCTION

Georges Pralus discovered in 1966 that a new cooking method, using vacuum packing that is used for food preservation, was more useful for chicken or terrine de foie gras (goose liver paté) than the former cooking method, because of the increased heat conduction with air removed from the vacuum packing. Vacuum cooking has since spread throughout France, especially for cooking in trains and airplanes.[1)2)] The raw materials to be vacuum cooked are packed in a plastic film bag, which is then evacuated and heated at a fairly low temperature (under 100℃), this being completely different from retort pouch foods. This new cooking method was introduced to Japan by a magazine on foods in 1988,[3)] and the appllication has gradually spread.

We have previously investigated the differences in food content and sensory evaluation between some vacuum cooked and normally cooked dishes.[4)] We noted that a cream stew cooked by the vacuum method resulted in separation of the sauce, and this present study examined the cause of this sauce separation.

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Abbreviations: BSA, bovine serum albumin; OVA, ovalbumin; TCA, trichloroacetic acid.

MATERIALS AND METHODS

Materials

Butter, wheat flour, concentrated bouillon, and chicken thigh meat were bought at a local market. The chemicals used were of reagent grade from Nacalai Tesque Ltd.

Preparation of the white sauce

An enameled pan (16 cm in diameter, 9 cm in depth) was heated for 1 min on a hot plate (300 W), and 15 g of butter was then put into it to melt for 1 min. Fifteen grams of wheat flour was next added and heated for 2 min and 30 s. After 80 g of cold milk had been added and heated for 2 min and 30 s, 107.5 g of cold milk was poured into the pan to be heated for 5 min until boiling to prepare the white sauce. The sauce was constantly stirred with a wooden spatula during this procedure. The amount of white sauce was 200 g, and its absolute viscosity measured at 60℃ by a B-type viscometer (Tokyo Keiki Ltd.) was about 50 mPa·s. In addition, 1 g of concentrated bouillon was added to 300 ml of boiling water to make a bouillon soup. The white sauce and bouillon soup were mixed at the ratio of 1 to 2, and 50 g of this mixture was used in the subsequent experiments.

Preparation of each sample

Four kinds of sample were prepared for the experiments. Forty grams of chicken thigh meat, 16.6 g of white sauce, and 33.4 g of bouillon soup were mixed and put into a bag, this mixture being called sample A. A sample using distilled water instead of bouillon soup is called sample B. The third sample didn't contain the chicken thigh meat of sample A, and is called sample C. The final sample included 16.6 g of white sauce and 33.4 g of distilled water, and is named sample D.

Cooking methods

1. Normal cooking

Forty grams of chicken thigh meat and 33.4 g of bouillon soup were mixed and heated at 100℃ for 30 min to get rid of the harshness. Finally, 16.6 g of white sauce was added to the mixture just before putting out the flame.

2. Vacuum cooking

Chicken thigh meat, bouillon soup, and white sauce (sample A) were put into a plastic film bag (Asahikasei Ltd.) and the pressure reduced to the lowest extent possible without crushing the meat, the bag then being sealed by using a vacuum packer (Tosei Denki Ltd.). This bag was heated at 90℃ for up to 60 min.

3. Open cooking

Sample A was put into a bag and sealed without reducing the pressure. After the upper part of the bag had been cut (open process), it was heated at 90℃ for up to 60 min.

All the cream stews made by using these three methods of cooking were at about pH 6.4.

Measurement of sauce separation in the cream stew during vacuum and open cooking

The evacuated or open process was conducted on the plastic film bags holding chicken thigh meat, bouillon soup, and white sauce (sample A), and samples were heated at 90℃ for 5, 10, 20, 30 and 60 min. After each solution had been poured into a graduated cylinder and left for 2 h at room temperature, the degree of separation of the sauce in the cream stew was observed. The dispersibility (%) of the sauce in the cream stew is represented by the formula (volume of precipitated part)/(total volume) × 100.

For another experiment, 0.1, 0.2 or 0.3 g of bovine serum albumin (BSA) or ovalbumin (OVA) was mixed with 33.4 g of bouillon soup and put into a plastic film bag with 16.6 g of white sauce, before the evacuated or open process was conducted. After heating at 90℃ for 60 min, the solution was left overnight in a graduated cylinder at room temperature, and the dispersibility was then measured.

Effects of bouillon and chicken thigh meat on the cream stew

Samples A, B, C and D were put under reduced pressure and heated at 90℃ for 60 min, the state of each cream stew then being compared with that before heating.

Measurement of the amount of protein eluted from the chicken thigh meat during cooking

Forty grams of chicken thigh meat and 50 ml of distilled water were put into a plastic film bag. The evacuated or open process was conducted, and each bag was heated at 90℃ for 5, 10, 20, 30 or 60 min. Just after each heating process, the meat was removed and the solution was poured into a graduated cylinder. The volume was measured, and 100 % trichloroacetic acid (TCA) was added to 8 %. After centrifuging (1,500 g × 20 min), the precipitate was recovered by filtration. This procedure was repeated at least 3 times until no turbidity occurred to collect as much of the water-soluble protein as possible. The amounts of protein were measured by the method of Kjeldahl.

Micro-observation of changes in the cream stew during cooking

Sample A was packed, evacuated and heated at 90℃ for 10 or 60 min. The state of the emulsion in each sample was then observed with a microscope (Nikon EFM) and compared with that before heating.

Unless otherwise stated, at least duplicates were independently assessed in each experiment, and the average ± standard deviation was calculated for each sample. Statistical differences were evaluated by using Student's *t*-test.

RESULTS AND DISCUSSION

State of the cream stew after normal or vacuum cooking

Photographs of the cream stew samples after normal and vacuum cooking are shown in Fig. 1. The cream stew after normal cooking (Fig. 1-A) was poured into a plastic film bag from an enameled pan for easy observation. This stew was uniform, and no separation of the sauce was apparent. However, separation was clearly observed in the sample after vacuum cooking (Fig. 1-B).

There are two clear differences between normal and vacuum cooking. One is the application of an evacuation process and the other is the order of addition of the materials as described in the MATERIALS AND METHODS section. We thought that the cause of the observed sauce separation in the

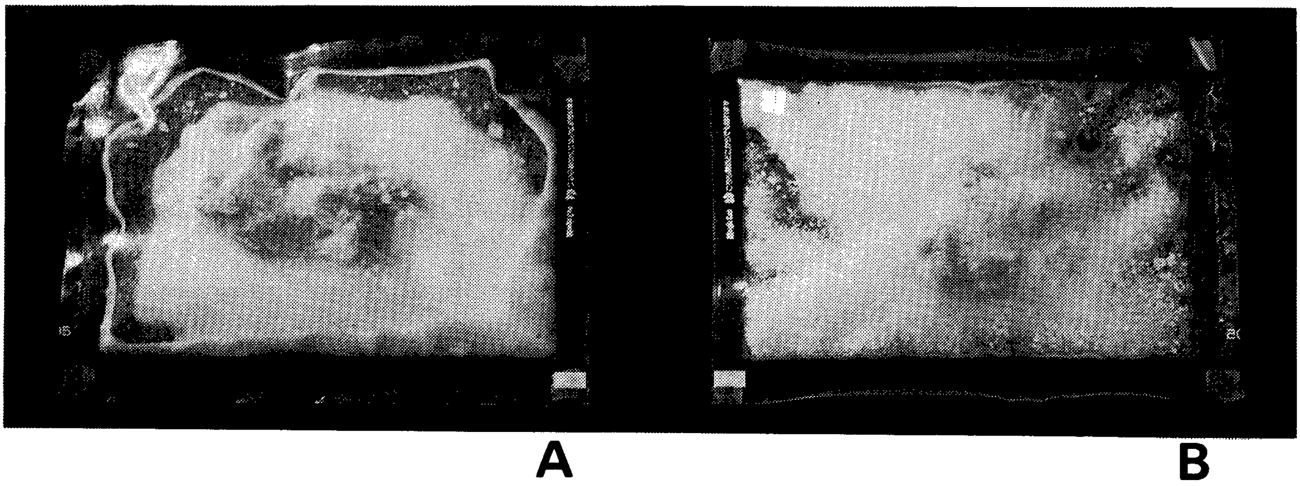

Fig. 1. Differences between vacuum and normally cooked cream stews

Forty grams of chicken thigh meat and 33.4 g of a bouillon soup were mixed and heated at 100℃ for 30 min. Finally, 16.6 g of white sauce was added to the mixture just before putting out the flame, and the mixture was poured into a plastic film bag (A). The same materials were put into a plastic film bag and the pressure reduced to the maximum extent possible without crushing the meat, the bag then being sealed and incubated at 90℃ for 60 min (B).

cream stew after vacuum cooking might have depended on these differences and we thus investigated.

Influence of evacuation on the cream stew

The participation of evacuation in the sauce separation during vacuum cooking was investigated. Sample A was packed into a bag, and 5, 10, 20, 30 or 60 min of vacuum cooking was conducted. After each sample had been vacuum cooked, the solution in the bag was poured into a graduated cylinder and the change in separation state of the cream stew during cooking was identified (Fig. 2). The total volume of the solution in the bag before cooking was 50 ml (Fig. 2-A) and increased with increasing cooking time, reaching 61 ml after 60 min of vacuum cooking (Fig. 2-F). No separation of the sauce in the cream stew was observed during the first 10 min of cooking; after that, however, the degree of separation gradually increased up to 60 min.

Next, the changes in dispersibility during vacuum and open cooking were identified by using sample A (Fig. 3). The dispersibility in each cooked sample didn't change during the first 10 min of cooking, but then decreased rapidly to about 60% after 30 min, and then more gradually to about 50% after 60 min. There was no significant difference between the cooking methods.

These results in Figs. 2 and 3 suggest that the sauce separation in the cream stew that occurred during vacuum cooking didn't depend on the evacuation procedure.

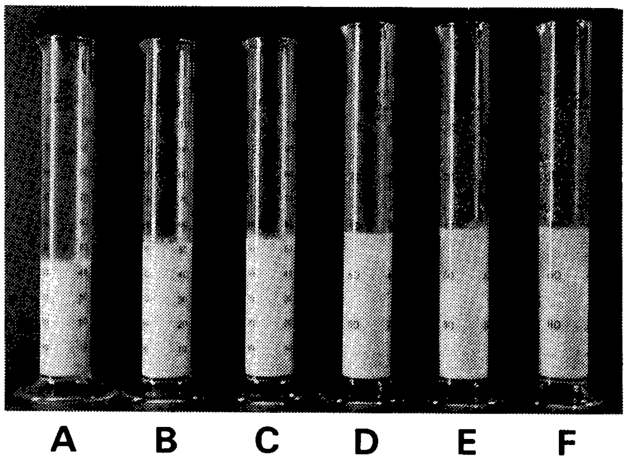

Fig. 2. Changes to cream stew during vacuum cooking

Chicken thigh meat, bouillon soup, and white sauce were evacuated (A) and then heated at 90℃. After 5 min (B), 10 min (C), 20 min (D), 30 min (E), and 60 min (F) of cooking, the solution from each sample was poured into a graduated cylinder and left for 2 h.

Effects of chicken thigh meat and bouillon on the cream stew

The second possibility was then investigated, after it had been found that the sauce separation in the cream stew occurring during vacuum cooking was not caused by the reduced pressure. Samples A, B, C and D were each vacuum cooked, and the state of each

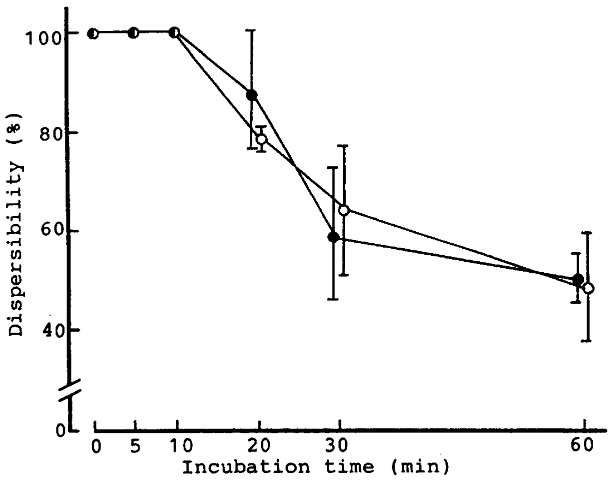

Fig. 3. Changes in the dispersibility of sauce in the cream stew

The mixture of chicken thigh meat, bouillon soup, and white sauce (sample A) was cooked by using vacuum (●) or open (○) cooking, and the change in dispersibility was evaluated. Dispersibility is presented as the ratio of the precipitated volume to the total volume. The bars show the standard deviation of three or four replicated measurements.

sample after cooking was compared with that before cooking to discover which material affected the state of the cream stew (Fig. 4).

No separation of the sauce in the cream stew was apparent in the sample containing all the materials (sample A) before cooking (Fig. 4-A); however, the sauce in the cream stew had separated after 60 min of vacuum cooking at 90℃ (Fig. 4-B). This separation was also apparent in sample B, containing distilled water instead of bouillon soup, after cooking (Fig. 4-C). On the other hand, vacuum cooking didn't make the sauce in the cream stew separate in samples C and D, neither of which included the meat (Figs. 4-D, E).

These results suggest that the sauce separation in the cream stew during vacuum cooking depended on the presence of meat, and led us to assume the participation of protein in the meat for this phenomenon to occur. We therefore monitored the change in the amount of protein eluted from the meat during vacuum cooking to examine this possibility.

Change in the amount of protein eluted from meat

To investigate the change in the amount of protein eluted from the meat, vacuum or open cooking at 90 ℃ was conducted for up to 60 min on samples containing 40 g of chicken thigh meat and 50 ml of distilled water instead of bouillon soup (Fig. 5). The amount of protein in each sample cooked under the reduced pressure or open condition represented about 0.02 g/50 ml at 0 min, 0.2 g/59 ml at 20 min, 0.25 g/60 ml at 30 min, and 0.3 g/61 ml at 60 min. There was no significant difference between the samples, indicating that the evacuation process didn't increase the elution of protein from the meat.

If the protein eluted from meat brought about the sauce separation in the cream stew during vacuum cooking, the amount of protein shown after 20 min of cooking in Fig. 3, this being the time at which the sauce started to separate, might be the minimum necessary to separate the sauce in the cream stew. We then selected BSA and OVA as soluble proteins to

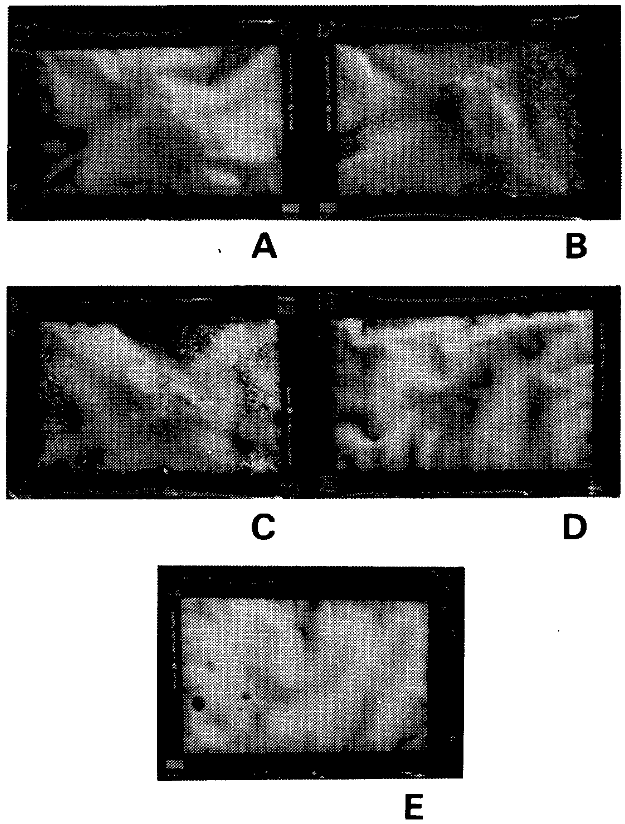

Fig. 4. Effects of chicken thigh meat and bouillon on the cream stew

After the chicken thigh meat, bouillon soup, and white sauce had been mixed (sample A) and evacuated (photo A), the mixture was heated at 90℃ for 60 min (photo B). The same procedure was conducted on the samples without just bouillon soup (sample B)(photo C), chicken thigh meat (sample C)(photo D), or both chicken thigh meat and bouillon soup (sample D)(photo E).

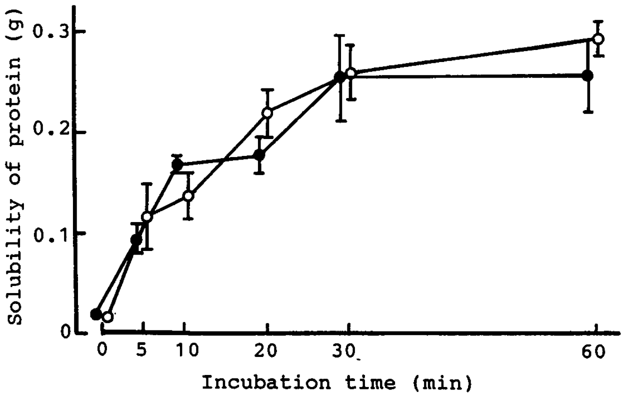

Fig. 5. Change in the solubility of meat protein during cooking

Chicken thigh meat in distilled water was heated at 90℃ by vacuum (●) or open (○) cooking. The amount of soluble protein from the meat was measured by the Kjeldahl method. The bars show the standard deviation of three replicated measurements.

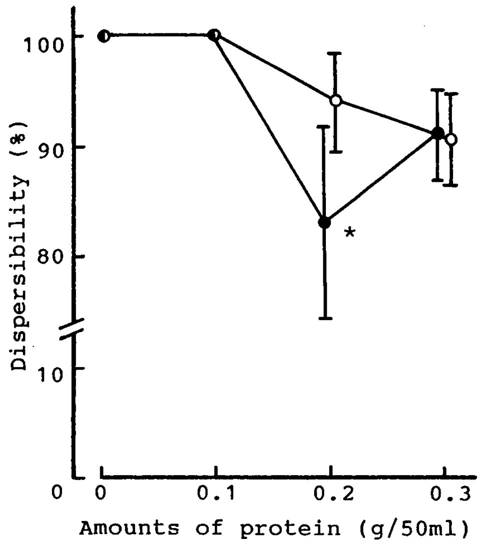

Fig. 6. Effects of BSA and OVA on the cream stew during cooking

Mixtures of white sauce and bouillon soup with various weights of BSA (●) or OVA (○) were heated at 90℃ by the vacuum cooking method. Each heated solution was left overnight and the dispersibility was measured. The bars show the standard deviation of three replicated measurements. *Indicates a significant difference between the samples at $p<0.05$.

test this hypothesis, and investigated their effects on the cream stew during vacuum cooking.

Effects of BSA and OVA on the cream stew

BSA or OVA was used instead of chicken thigh meat to investigate the effects of soluble protein on the cream stew during vacuum cooking. The cream stew without or with 0.1, 0.2 or 0.3 g of BSA or OVA was prepared by vacuum cooking for 60 min at 90℃, and the dispersibility in each sample was measured (Fig. 6).

In the cream stew without or with 0.1 g of BSA or OVA, no separation occurred. However, the addition of 0.2 or 0.3 g of either of the two proteins made the sauce in the cream stew separate. The dispersibility of the sauce in the cream stew containing OVA was 94.0 ± 4.6 and 90.5 ± 4.2 %, while in the one containing BSA, it was 83.2 ± 8.8 and 91.0 ± 4.0 %, each with 0.2 or 0.3 g of protein, respectively. Although it is not known why the dispersibility generated by adding 0.2 g of BSA was lower than that with the addition of 0.3 g of BSA, this may have depended on a difference in the coagulation of micelles, or the requirement for an optimum concentration to separate the sauce in the cream stew.

Micro-observation of the cream stew during vacuum cooking

After the chicken thigh meat, white sauce, and bouillon soup had been put into a bag and evacuated, 10 or 60 min of vacuum cooking at 90℃ was conducted, and changes in the micelles were observed with the microscope (Fig. 7). The small micelles derived from the white sauce were dispersed uniformly in the emulsion before cooking, and some bigger lipid particles from the meat (L) were also observed (Fig. 7-A). However, the state of the micelles was changed by 10 min of vacuum cooking (Fig. 7-B). A coagulum of micelles (arrows) was generated here and there and the uniformity collapsed. After 60 min of vacuum cooking, the sauce in the cream stew had separated, so that just the supernatant was observed (Fig. 7-C). Only lipid particles from the meat and milk and some pieces of meat were apparent instead of the micelles. These results suggest that the micelles derived from the white sauce coagulated into bigger particles, leading to separation of the sauce in the cream stew.

The micelles derived from the white sauce were stable, and no changes were observed when only milk or white sauce with bouillon was subjected to vacuum cooking (data not shown), indicating that the sauce separation in the cream stew during vacuum cooking depended on the soluble protein from the meat.

Judging from these results, we think that the mechanism for the separation of sauce in the cream stew starts with the proteins eluted from the meat being adsorbed to the micelles derived from the white

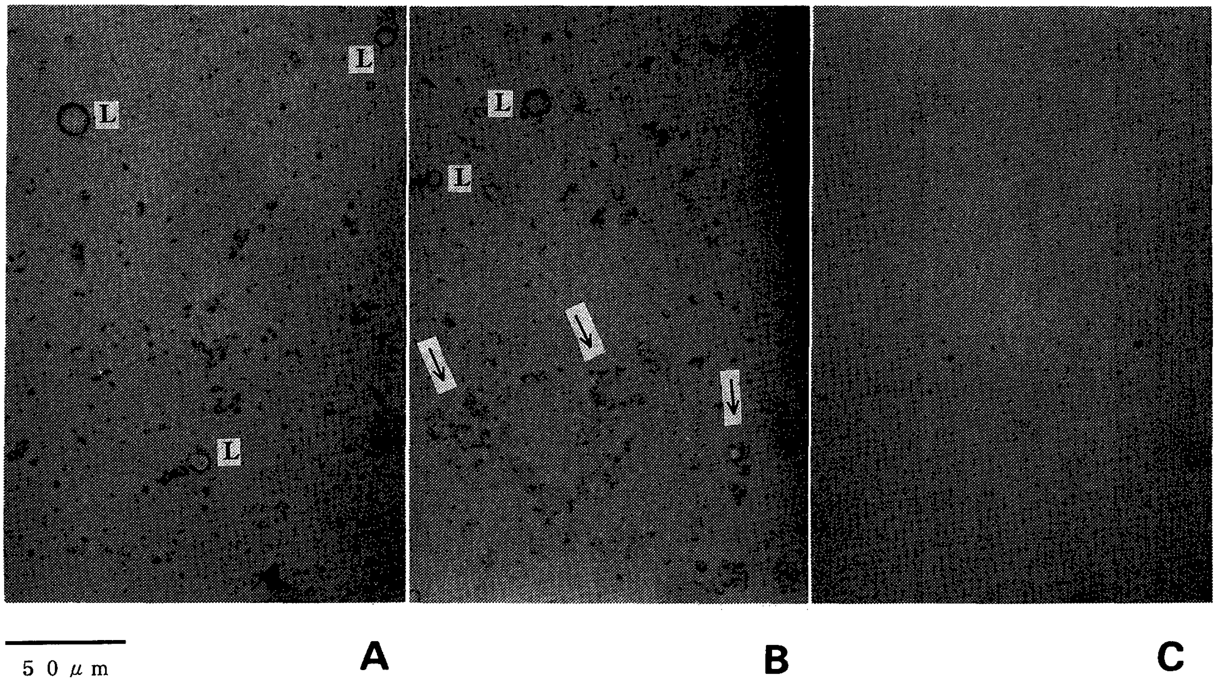

Fig. 7. Changes in the emulsion during vacuum cooking (× 400)

Chicken thigh meat, bouillon soup, and white sauce were made into the packages, evacuated (A), heated at 90℃ for 10 min (B) or for 60 min (C), and finally examined under a microscope. L identifies the larger lipid particles from meat, the other smaller particles being micelles derived from white sauce. Arrows show the coagulation of micelles.

sauce. These are then denaturated by heating so that some interactive bond between proteins, like disulfide bonding, is generated. The micelles then aggregate and their stability decreases, until separation of the sauce in the cream stew finally occurs.

It is known that proteins are easily adsorbed to an oil-water interface in an emulsion, so that denaturation and coagulation of proteins occur.[5)-8)] Dickinson *et al.* have reported that β-lactoglobulin denatured and polymerized through disulfide bonds at the oil-water interface in an emulsion.[9)] These reports support our hypothesis, although details of this phenomenon were not then known.

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Sauce Separation in Cream Stew during Vacuum Cooking

真空調理中に生じるクリームシチューのソース部分の分離について

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16.6gのホワイトソース，40gの鶏もも肉，33.4gのブイヨンスープから真空調理法を用いてクリームシチューを作ったところ，クリームシチューのソース部分が分離した．この現象は，減圧処理のいかんに関わらず60分間90℃で調理することにより生じたが，鶏もも肉を材料から除いたものでは起こらなかった．タンパク質は鶏もも肉から調理時間とともに溶出し，調理終了後約300mgに達していた．鶏もも肉の代わりに200mgまたはそれ以上の牛血清アルブミンあるいは卵白アルブミンを添加すると，クリームシチューのソース部分の分離が生じた．これらのことから，真空調理中に生じるクリームシチューのソース部分の分離は，減圧処理によるものではなく，調理中に肉より溶出してくる筋漿タンパク質によるものであることが判明した．

キーワード： 真空調理，ホワイトソース，分離，可溶性タンパク質，ミセル，クリームシチュー．