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ABSTRACT

The Problem of Drip Loss in Packaged Fresh Meat

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Freshly cut meat surfaces accumulate cellular fluids to a varying extent depending upon animal species, age, anatomical part, and pH of the muscle. Freezing and thawing greatly increase the drip fluid. In the fresh meat market, drip is frequently the reason for rewrapping a meat package. Moreover, when the housewife freezes meat for later use, as a majority in the U. S. does, three percent or more of the meat weight may be lost as drip.

Fast freezing, when compared with slow freezing, reduces drip loss, but the weight decrease is still greater than than in fresh meat.

Steaks may be dipped in a solution of salt and polyphosphates to give marked reduction of fluid loss even after freezing and thawing. As a process which could be applied in commercial operations, it was proposed to inject large cuts of meat with three percent of a salt-phosphate solution by means of a head carrying multiple needles.

The polyphosphates differ not only in extent of effect on drip, but also in duration of this effect. Sodium tripolyphosphate reduces drip over a short time interval, such as two or twenty-four hours after injection, but not after forty-eight hours. However, potassium tetrapyrophosphate remains effective for at least forty-eight hours.

Salt concentration is also a factor, apparently requiring fifteen percent or above for best results.

Method of applying the solutions shows significant differences, dipping decreasing the amount of drip several fold over that for injection. Salt solutions (fifteen percent) with sodium and potassium pyrophosphates, disodium orthophosphate, or sodium hexametaphosphate proved to be effective in decreasing Na_2HPO_4

drip loss. However, the most favorable results were found with a combination of sodium pyrophosphate with tripoly- or hexametaphosphate.

Top rounds (*semimembranosus*, *adductor*, *gracilis* muscles), bottom rounds (*semitendinosus*, *biceps femoris* muscles), and strip loins (*longissimus dorsi*, *multifidus dorsi* muscles) from U. S. Choice, U. S. Good, and U. S. Standard were injected with a solution of 15% salt + 1% $Na_4P_2O_7$ + 1% $(NaPO_3)_6$. After a forty-eight hour holding period, steaks were cut, packaged, and held fresh, or frozen and later thawed. With the steaks held fresh, Standard grade showed significantly less drip fluid than the other two grades.

Freezing and thawing altered these relations somewhat. The treatment difference was still significant, but the grade difference disappeared and animal variation within grade appeared. Also greater variability in steaks within a grade was evident. In all cases, injection decreased drip.

KURZFASSUNG

Das Problem des Gewichtverlustes durch Abtropfen in Verpacktem, Frischem Fleisch

tippna

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An frischgeschnittenen Oberflaechen von Fleisch sammelt sich eine Zellfluessigkeit an, deren Menge von der Tierart, Alter, anatomischen Teil und pH der Muskel abhaengig ist. Frieren und Auftauen des Fleisches erwirkt eine Zunahme in der Menge dieser Zellfluessigkeit. In Fleischerlaeden macht diese Fluessigkeit haeufig eine Neuverpackung des vorher eingewickelten Fleischstueckes notwendig. Wenn die Hausfrau das frische Fleisch fuer spaeteren Gebrauch selbst einfriert, wie das in USA ueblich ist, werden 3% oder mehr durch Abtropfen von dem Fleischgewicht verloren.

Schnellfrieren, im Gegensatz zu langsamem frieren erniedrigt den Verlust durch Abtropfen, jedoch ist dieser Gewichtsverlust geringer in frischem ungefrorenen Fleisch.

Steaks koennen in eine Fluessigkeit, bestehend aus Kochsalz und Polyphosphat, eingetaucht werden um eine markante Verminderung des Abtropfens, selbst nach frieren und tauen zu erzielen. Als Moeglichkeit dieses Verfahren handelsmaessig durchzufuehren wurde vorgeschlagen groessere Fleischstuecke mit einer 3% Kochsalz-Phosphat Loesung mittels einer Vorrichtung mit zahlreichen Injektionsnadeln zu impfen.

Die Polyphosphate zeigen nicht nur Unterschiede in ihren Einfluss auf das Abtropfen sondern auch in ihren Nacheffekten. Natrium-tripolyphosphat reduziert das Abtropfen ueber eine kurze Zeitspanne von zirka 2 bis 24 Stunden nach der Impfung jedoch nicht fuer 48 Stunden. Im Gegensatz zeigt Kalium-tetraphosphat einen Effekt fuer wenigstens 48 Stunden.

Ein weiterer Faktor ist die Konzentration von Kochsalz die anscheinend 15% oder hoeher fuer beste Resultate sein muss.

Auch zeigt die Anwendungsmethode fuer diese Loesungen bedeutende Unterschiede, z.B. vermindert Eintauchen das Abtropfen erheblich mehr als Einimpfung.

Eine 15% Kochsalzloesung zusammen mit Natrium- oder Kalium-pyrophosphat, Di-natrium orthophosphat oder Natrium hexametaphosphat haben sich fuer das Reduzieren von dem Abtropfen als wirkungsvoll erwiesen. Beste Resultate wurden mit einer Verbindung von Natrium-pyrophosphat mit tripoly- oder hexametaphosphat erzielt.

Fleischschnitte wie "Top Rounds" (musc. semimembranosus und adductor). "Bottom Rounds" (musc. semitendinosus und biceps femoris) und "Strips" (musc. longissimus dorsi und multifidus) in der zweiten (U.S. Choice), dritten (U.S. Good) und vierten (U.S. Standard) Qualitaetsklasse wurden mit einer Loesung von 15% Kochsalz $+$ 1% $Na_4P_2O_7$ $+$ 1% $(NaPO_3)_6$ geimpft. Nach 48 Stunden wurden diese Steaks geschnitten, verpackt und frisch wie auch gefroren und getaut untersucht. Die Standard Qualitaetsklasse der frisch gehaltenen Steaks zeigte erheblich weniger Abtropfen als die anderen zwei Klassen. Frieren und Tauen veraenderte dieses Verhaeltnis etwas. Die Art der Behandlung des Fleisches war weiterhin von Bedeutung, jedoch verwischten sich die Resultate innerhalb der Qualitaetsklassen und Unterschiede zwischen Fleisch von verschiedenen Tieren innerhalb einer Klasse traten hervor. Es wurden ferner groessere Unterschiede in den Steaks innerhalb einer Qualitaetsklasse beobachtet. In allen Faellen aber wurde das Abtropfen durch Impfung reduziert.

THE PROBLEM OF DRIP LOSS IN PACKAGED FRESH MEAT

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Loss of muscle juice from meat is undesirable for esthetic as well as economic and nutritional reasons. The presence of free juice in a meat package will cause rejection by a customer in spite of whatever desirable qualities may be evident. If meat is frozen and thawed, it is especially prone to show large quantities of drip fluid. Possibly for this reason, published reports of investigations are concerned with those factors affecting drip losses in meat which has been frozen and thawed.

Howard (1956) sawed meat blocks from frozen carcasses and then allowed them to thaw under different physical conditions. When they were supported on glass grids, blocks dripped less than those held in a plastic bag, indicating that in contrast to supporting the meat, contact of tissue with the fluid decreases drip. Muscle fiber direction has significance since drip is greater along the fibers than across them. The application of pressure to the meat increases drip (Empey, 1933). Fluid loss rate differs with time, rising rapidly to the first 24 hours, and then slows gradually to 72 hours.

Animal grade is also a factor. Howard and Lawrie (1956) found drip from frozen and thawed quarters to be higher in Canner and Cutter cattle than in Grades 1 and 2.

Muscles within a carcass show differences. The *longissimus dorsi* releases twice the fluid that *psoas major* does (Bouton, Howard, and Lawrie, 1957). Leg muscles represent the other extreme from *psoas*.

Drip from large cuts such as ribs is relatively small compared with that of cuts having a larger surface area in relation to volume (Ramsbottom and Koonz, 1939). Howard (1956) found less drip from meat blocks 3 cm. thick than from those 1 cm. thick.

Relationship of drip to meat pH has long been known. Empey (1933) noted that above pH 6.3, little or no fluid was recovered. Sair and Cook (1938) adjusted the pH of ground beef and then froze and thawed it. Maximum drip occurred at pH 4.8 to 5.2, and at pH 6.0 drip had decreased to about the same as that of unfrozen meat. Similar results were reported by Bouton, Howard, and Lawrie (1957). They stated that the quantity of drip from thawed meat was inversely related to pH.

Age of meat before freezing is a significant factor (Ramsbottom and Koonz, 1940; Sair and Cook, 1938). A maximum of drip is seen in loin steaks cut one day after slaughter, and then declines gradually from about seven days on.

The effect of freezing temperature has received more attention than any other variable. Rib steaks were frozen at different temperatures and then thawed (Ramsbottom and Koonz, 1939). Compared with 20°F. (-7°C.), -10°F. (-23°C.) freezing reduced drip about 20 percent, and at -50°F. (-46°C.), about 50 percent. For short storage periods, -30°F. (-34°C.) decreased fluid loss by 15 percent (Ramsbottom and Koonz, 1940). Hiner _et al_. (1945) also found large differences in the effect of freezing temperatures. Their data indicated that the percent drip loss decreased from 12.1 at 18°F. (-8°C.) to 1.9 at -114°F. (-81°C.). In addition, Ramsbottom and Koonz (1941) point out that drip declined by one-third when the freezing temperature was lowered from 10°F. (-12°C.) to -30°F. (-34°C.). According to Pearson and Miller (1950), there is some evidence that drip increases rather than decreases with low freezing temperatures.

Curiously enough, when freezing at one temperature and storing at another, the drip pattern is set by the first cold experience. (Ramsbottom and Koonz, 1941). These workers reported that a 10°F. (-12°C.) effect is not corrected by -30°F. (-34°C.) later, or -30°F. (-34°C.) one spoiled by 10°F. (-12°C.).

Several other factors, beside freezing and storage temperatures, have been studied in regard to the drip loss of frozen meat. According to Ramsbottom and Koonz (1940), the longer meat is stored in the frozen state, the smaller the amount of drip during thawing. However, contrasting results have been reported by Pearson and Miller (1956). Another factor that has been considered is the thawing temperature. Paul and Child (1937) have suggested that this factor has little or no influence on the fluid loss during thawing. Repeated freezing and thawing, as might be expected, does influence drip loss. This manner of handling meat breaks down the muscle tissue and causes the liberation of additional fluid. (Nichols and Mackintosh, 1952).

Drip loss is now recognized as only one phase of general meat behavior known as water-holding capacity, which is in turn, the empirical effect of protein hydration. This major problem was reviewed so comprehensively by Hamm (1960) that nothing would be added by repetition.

One method practiced widely to increase water-holding by meat is addition of salt, phosphate, or other chemical salts. Of the large literature on this subject, most of the reports are concerned with meat at pH above that of average carcass meat (Grau, Hamm, and Baumann, 1953), high levels of phosphates (Hamm, 1955), or salt concentrations unsuitable in fresh meat (Hamm, 1953; Hamm, 1957; Wierbicki, Kunkle, and Deatherage, 1957; Hellendoorn, 1962) to mention only a few references. Cuts of meat perfused with 10 percent of 16 percent salt solution showed reduced drip loss when frozen and thawed (Wierbicki, Cahill, and Deatherage, 1957).

Salt concentrations of 1 to 3 percent increased water retention in ground meat held unfrozen, and even after freezing and thawing, less free water was found than with fresh untreated controls (Suri, 1957).

Water retention by ground meat suspended in solutions of salt or salt and pyrophosphate was determined by Swift and Ellis (1956). Salt in concentrations of 0.85 percent caused swelling of meat to 125 percent of that in controls. Salt, 0.85 percent and tetrasodium-disodium pyrophosphate 0.5 percent, increased meat volume to 140 percent.

In earlier experiments, Bendall (1954), using the meat volume method, reported that in 0.5 percent NaCl solutions, ground meat swelled to 118 percent and phosphates further increased the salt effect. Pyrophosphate was unique in this respect, 0.13 percent pyrophosphate, and 0.5 percent NaCl raising meat volume to 150 percent.

Salt and phosphate solutions were employed for dipping steaks or small roasts to decrease drip after packaging (Hopkins and Zimont, 1962).

This paper presents data on some of the factors affecting drip loss and chemical treatments for decreasing the drip loss of meat displayed fresh or frozen and thawed.

METHODS

Freezing Temperature, Films, and Freezer Storage Time

Investigations were conducted to determine the influence of temperature, packaging films, and storage time on drip loss of top and bottom round steaks. The temperatures used were 40°F. (4°C.), -10°F. (-23°C.), and/or -40°F. (-40°C.).

The first study involved three temperatures and three packaging films. The packaging films were ones commonly employed in retail meat markets and were designated as A, B, and C, and had the following composition: A, polyethylene coated cellophane; B, moisture-proof, heat-sealable cellophane; and C, irradiated polyethylene. Wholesale rounds from the right side of two U. S. Good carcasses were used. Both the top and bottom rounds were cut one-half inch thick and then wrapped in one of the three films. The packaged steaks were then displayed at 40°F. (4°C.) or frozen. Steaks frozen at -40°F. (-40°C.) were removed from this temperature after 24 hr., placed in paper boxes, and stored at -10°F. (-23°C.). The steaks which were frozen were later thawed and stored at 40°F. (4°C) for four days. They were then unwrapped and the amount of drip measured.

The second experiment was undertaken to study the weight loss of top and bottom rounds frozen at -10°F. (-23°C.) and then stored at the same temperature for two and four weeks. The right and the left top and bottom rounds from a U. S. Good beef carcass were used in this experiment. All cutting, packaging materials, and freezing and thawing procedures followed those outlined for the first experiment.

Application of Salt-Phosphate Solutions

Solutions containing salt and phosphates were tested for decreasing the drip loss of beef steaks. The solutions were applied to the meat in one of two ways, (1) dipping steaks into the solution, or (2) injecting the solution into meat cuts.

Dipping

The dipping solution contained 15.0% NaCl and 1.0% $Na_4P_2O_7$. The steaks were cut three-quarter inch thick from U. S. Commercial boneless loin strips and top rounds. Alternate steaks were immersed in the solution for 1 minute, drained for 20 seconds, and packaged in fresh meat, heat-sealable cellophane. Weight gains were from 2.5% to 3.5%. The untreated steaks were used as controls. Four dipped and four control steaks were held either at 40°F. (4°C.) for three days or frozen and stored at -10°F. (-23°C.) and then thawed for three days.

Each steak was weighed to within 0.1 g. before packaging and at the end of the experiment was stripped with a rubber scraper and reweighed. The percent change in the weight of the meat was considered as percent drip loss.

Injecting

Tetrasodium pyrophosphate or disodium orthophosphate gave some precipitate from salt solutions, which could be troublesome in plugging injection needle openings. Tetrapotassium pyrophosphate solutions with salt had less tendency to precipitate than did the corresponding sodium salt. When sodium tripolyphosphate or sodium hexametaphosphate were combined with the tetrasodium pyrophosphate, little or no precipitate formed.

The best method for preparing the solutions was to dissolve the phosphate first, and slowly add the salt. Both the salt and the phosphates were approved for food use.

An injection head with 12 needles spaced 1 inch apart was used for injecting the solutions. Each needle contained 10 holes equally spaced over a length of 2 inches for the loins and 3½ inches for the rounds. Solution quantity was controlled by an air-activated proportioning pump. Cuts from the round were injected at 150 lb. pressure and loins at 100 lb. Weight gains were from 2.5 to 3.1 percent.

To check the distribution of injected solution, nitrite to give 30 ppm in the meat, was added in the early experiments. By two days, the interior of the cuts showed nitrosomyoglobin across the entire cut surface.

Cutting was done with a rotating blade slicer set to give steaks 1/2 inch thick for top and bottom round and 3/4 inch thick for the strip loin steaks. In some of the preliminary experiments, the steaks were laid on rough porous papers in a 40°F. (4°C.) cooler for 1 hour to allow maximum oxymyoglobin formation (blooming). The steaks were then placed in pouches and sealed by electrical impulse. Mylar-polyethylene bags were used in the early experiments, whereas the pouches for the principal experiment were made of irradiated polyethylene. The packaged steaks were handled in the same manner as those in the dipping experiments.

Steaks in the preliminary experiments were from U. S. Good top rounds. The experimental material in the principal experiment consisted of 2 carcasses (matching right and left sides) from each of the following U.S.D.A. grades: low Choice, average to low Good, and average to low Standard. Three wholesale cuts were used for injection purposes: top round (primarily the *semimembranosus*, *adductor*, and *gracilis* muscles), bottom round (the *biceps femoris* and *semitendinosus* muscles), and strip loins (the *longissimus dorsi* and *multifidus dorsi* muscles from the tuber coxae to the twelfth thoracic vertebra). To obtain uniform, representative samples, the steaks were numbered from

1 to 8 beginning at the anterior end of each cut. The odd-numbered steaks were taken for the fresh display part of this experiment, and the even-numbered ones allotted to the freezing and thawing phase. Steaks used for this phase were placed on flat trays and frozen and stored at -10°F. (-23°C.). They were subsequently thawed for three days under the same conditions as the fresh display steaks.

A slightly different method of measuring drip loss was used for the principal experiment. The unwrapped steaks were put in a "V"-shaped metal tray with a pouring lip, so that the juice as it was scraped from the steaks, could be collected into a volumetric flask. The drip remaining on the film was then washed into the same flask. Solutions were then made to volume and aliquots removed for nitrogen determinations by the Miller and Houghton (1945) procedure. Amount of drip was the difference in the weight of the meat at the time of packaging minus the "scraped" meat weight.

The data for the principal experiment were analyzed using the nested and mixed factorial arrangements of treatments (Snedecor, 1956). Due to the heterogeneity of variance between the fresh, and freezing and thawing phases, the data from these two phases were analyzed separately.

RESULTS AND DISCUSSION

Freezing Temperature, Films, and Freezer Storage Time

A summary of the data and the analysis of variance for the first experiment are presented in Tables 1 and 2 respectively. These data indicate that regardless of the packaging film or temperature, the top round steaks lost more weight than the bottom round steaks (6.03% vs. 5.02%). Freezing, as well as the freezing temperature, affected the amount of drip in the package. When the meat was stored at 40°F. (4°C.) for 4 days immediately after cutting, the average percent drip was 2.90 (Table 1). The frozen steaks, however, lost more weight than the fresh steaks, regardless of freezing temperature. Freezing temperatures *per se* affected not only the amount of weight loss within packaging films, but tended to bring out differences between packaging films. Steaks wrapped in the same film and frozen at -10°F. (-23°C.) always had more drip than the steaks frozen at -40°F. (-40°C.) after being thawed and stored for 4 days (Table 1). Although the average drip loss was similar for all the films when the steaks were frozen at -10°F. (-23°C.)., steaks frozen at -40°F. (-40°C.) and wrapped in Film C lost 1.52% less than those wrapped in Film A. Furthermore, steaks wrapped in Film C

Table 1. Top and Bottom Round Steaks Packaged in Different Films, Held Fresh, Frozen at Two Temperatures, and Thawed Average Drip Loss, Percent

Film	A			B			C			O
	Top	Bottom	Avg.	Top	Bottom	Avg.	Top	Bottom	Avg.	Overall Avg.
40°F. (4°C.)	3.18	2.55	2.87	3.55	2.98	3.27	2.93	2.91	2.57	2.90
-10°F. (-23°C.)	8.19	7.64	7.91	7.74	6.95	7.35	8.26	6.38	7.32	7.53
-40°F. (-40°C.)	7.58	6.33	6.96	6.62	5.54	6.08	6.23	4.64	5.44	6.16
Avg.	6.32	5.51		5.97	5.16		5.81	4.41		
Overall Avg.	5.92			5.57			5.11			

Table 2. Analysis of Variance of Drip Loss from Top and Bottom Round Steaks Packaged in Three Different Films and Frozen and Thawed

Source	d.f.	Mean square	F
Total	35		
Steak	1	11.22	26.09**
Temp.	2	63.86	148.51**
Film	2	1.30	3.02
St x T	2	0.52	1.21
St x F	2	0.26	-
T x F	4	0.77	1.79
St x T x F	4	0.06	-
Error	18	0.43	

**P<.01

generally lost less weight, with the exception of the top rounds frozen at -10°F. (-23°C.), than the steaks wrapped in the other two films.

Results of the second experiment are presented in Tables 3 and 4. These data suggest that the only significant variable was that due to the 2 week extended time in storage (Table 4). There was a 1.62% decrease in drip in the steaks stored for 4 weeks as compared to those steaks stored for 2 weeks. Although the previous experiment indicated a difference in the drip loss of top and bottom round steaks, there was no statistically significant difference between them in this investigation.

These two experiments indicate that the drip loss of beef steaks (1) increases when steaks are frozen and thawed, (2) decreases when steaks are frozen at -40°F. (-40°C.) instead of -10°F. (-23°C), and (3) may be influenced by the packaging film.

Dipping

Dipping steaks in a solution containing 15.0% NaCl and 1.0% $Na_4P_2O_7$ significantly decreased the drip loss when they were displayed (Table 5). These data also indicate that there was no significant difference in the average percent weight loss of the loin and the top round steaks.

The average fluid loss for the control and dipped loin steaks was 1.9% and 1.3% respectively. However, the dipped top round steaks only lost 1.0% in weight, while the control steaks lost 2.1% in weight

Table 3. Top and Bottom Round Steaks Packaged in Different Films. Held Frozen at -10°F. (-23°C.) for 2 or 4 Weeks. Average Drip Loss, Percent

Film	Top Round		Bottom Round	
	Frozen 2 Weeks	Frozen 4 Weeks	Frozen 2 Weeks	Frozen 4 Weeks
A	6.95	5.15	7.36	6.04
B	6.27	5.62	6.96	5.07
C	6.25	5.15	7.72	4.76
Average	6.49	5.30	7.35	5.28

Table 4. Analysis of Variance of Drip Loss from Top and Bottom Round Steaks Wrapped in Three Different Films, and Held Frozen for 2 or 4 Weeks

Source	d.f.	Mean square	F
Total	23		
Steak	1	1.05	1.88
Film	2	0.43	-
Sampling	1	15.76	28.14**
St x F	2	0.19	-
St x Sa	1	1.16	2.07
F x Sa	2	0.30	-
St x F x Sa	2	0.73	1.30
Error	12	0.56	

**P<.01

during storage. Thus, dipping decreased the amount of fluid in the packages of the loin steaks by 30.7%, while the fluid content was decreased by 53.0% in the packaged round steaks during dipping.

Table 5. Analysis of Variance, Average Drip Loss for Control and Dipped Steaks, Top Round and Strip Loin Steaks Held Fresh

Source	d.f.	Mean square	F
Total	31		
Treatment	1	5.81	10.02**
Steak	1	0.01	
T x St	1	0.59	1.02
Error	28	0.58	

**P<.01

Steaks from the same cuts of beef frozen and then thawed responded differently to the treatment than those displayed fresh. Not only did all the dipped steaks lose less weight than the corresponding controls, but the loin steaks reacted to the dipping treatment differently than did the top round steaks (Table 6).

Table 6. Analysis of Variance, Average Drip Loss for Control and Dipped Steaks, Top Round and Strip Loin. Steaks Frozen and Thawed

Source	d.f.	Mean square	F
Total	31		
Treatment	1	19.83	49.34**
Steak	1	4.31	4.27*
T x St	1	17.33	17.16**
Error	28	1.01	

**P<.01
*P<.05

The average drip loss was 2.2% for the loin steaks and 2.9% for the top round steaks. In the case of the loin steak a difference of 1.0% was found between the weight loss of the dipped and controls (2.72% vs. 1.70% respectively). However, the difference between the dipped and control top round steaks was 3.9% (4.9% vs. 1.0% respectively). These data suggest that the dipping treatment was much more effective in decreasing the loss of fluid from the tissue of thawed top round steaks than loin steaks.

This experiment indicates that dipping top round and loin steaks in an aqueous solution containing 15.0% NaCl and 1.0% $Na_4P_2O_7$ decreases the drip loss during the time they are displayed either fresh or during thawing. Regardless of the manner in which the steaks were handled, the treatment appeared to be more effective for the top round than for the loin steaks.

Injecting

Preliminary Experiments: These experiments were conducted to include the following variables: (1) the post-injection time necessary to decrease drip loss, (2) the optimum level of salt concentration, and (3) the effectiveness of different salt-phosphate solutions. The experimental material was U. S. Good top rounds from 70 to 80 pound wholesale rounds. The top round cut was removed approximately three days post-mortem and injected approximately 5 days post-mortem.

In these experiments, the differences between animals was confounded with treatment since one side was injected and the other side used as a control. However, the anatomical location for each pair of treated and control steaks was kept constant. For statistical analysis, the observed value was the difference between control-treated. Thus, a negative value denoted a decrease in drip loss due to the treatment.

The first series of experiments were conducted to study post-injection time, salt-concentration, and time between cutting and packaging. Results indicated that the phosphate in the injection solution influenced the time after injection for which the drip loss would be decreased. For example, a solution of 15.0% NaCl and 1.0% $Na_5P_3O_{10}$ was effective 2 hours and 24 hours post-injection but not at 48 hours. However, a solution of 15.0% NaCl and 1.0% $K_4P_2O_7$ was effective at 24 and 48 hours post-injection. This suggests that for practical application it would be necessary to test all treatments 48 hours post-injection. Therefore, the remainder of the studies was conducted using a 48-hour time interval between injection and cutting.

In another phase of the experiment, the salt concentration and its effect on two different phosphate solutions was studied. Injection solutions with the following compositions were used: Trial 1 -

15.0% NaCl, 10.0% or 20.0% NaCl plus 1.0% tripolyphosphate; Trial 2 - 5.0% NaCl, and 5.0 NaCl plus 2.0% tetrasodium or potassium pyrophosphate. The only solutions which decreased drip loss were the 15.0% salt and the 20.0% salt plus 1.0% tripolyphosphate. Also, the injection solutions used in the post-injection trials containing 15.0% salt were effective. Therefore, further experiments were conducted to determine the effect of injecting different phosphates in 15% salt solutions.

Based on the differences determined in the solubilities of the phosphates, the next experiment included the following solutions: (1) 15.0% NaCl + 1.0% $Na_4P_2O_7$ (filtered), (2) 15.0% salt + 1.0% $K_4P_2O_7$, and (3) 15.0% salt + 0.4% $Na_4P_2O_7$ + 0.6% $K_4P_2O_7$. These solutions were applied to the meat by dipping the steaks or injecting the cuts. The results are presented in Table 7. It is apparent from these data that the dipping process has greater effectiveness in decreasing drip loss. Furthermore, the combination of pyrophosphates was more than twice as effective as the separate pyrophosphates.

Table 7. Top Round, Treated as Steaks, or Injected with 15% NaCl + Pyrophosphate. Average Drip Loss Difference Between Control and Treated

	15.0 % NaCl 1.0% $Na_4P_2O_7$	15.0% NaCl 1.0% $K_4P_2O_7$	15.0% NaCl 0.4% $Na_4P_2O_7$ 0.6% $K_4P_2O_7$	Total
Dipped	-0.56	-1.11	-1.58	-3.25
Injected	.15	.29	- .26	.18
Total	- .41	- .82	-1.84	

In the second trial the injection solution consisted of 15.0% NaCl plus 0.4% $Na_4P_2O_7$ and 0.6% $K_4P_2O_7$, 1.0% Na_2HPO_4 or 1.0% $(NaPO_3)_6$. Table 8 suggests that the most effective treatment overall was the one containing $(NaPO_3)_6$. However, there was no statistically significant difference between treatments (Table 9). These data also show that a 1 hour interval between cutting and packaging times does not mask treatment differences, even though the steaks held 1 hour prior to packaging did lose more weight (2.75 vs. 2.50%). Similar results were obtained in earlier studies in regard to this factor.

Table 8. Top Round, Injected with 15% NaCl + Pyrophosphate, + Orthophosphate, or + Hexametaphosphate. Steaks Bloomed or Not Bloomed. Average Drip Loss Difference Between Control and Treated

	15.0% NaCl 0.4% $Na_4P_2O_7$ 0.6% $K_4P_2O_7$	15.0% NaCl 1.0% Na_2HPO_4	15.0% NaCl 1.0% $(NaPO_3)_6$	Total
Steaks not bloomed	-0.22	-0.51	-0.42	-1.14
Steaks bloomed	- .18	- .21	- .35	- .74
Total	- .40	- .72	- .77	

Table 9. Analysis of Variance of Results in Table 8

	d.f.	Mean square	F
Total	11		
Treatment	2	0.040	NS
Bloom	1	.053	NS
T x B	2	.021	NS
Error	6	.082	

Due to the consistent decrease in weight loss by injecting the salt-pyrophosphate combination, an experiment was conducted using other phosphate combinations. The solutions used were (1) 15% NaCl + pyro 1.0% $Na_4P_2O_7$ + 1% $Na_5P_3O_{10}$*; (2) 15% NaCl + 1.0% $Na_4P_2O_7$ + 1% $(NaPO_3)_6$, meta and (3) 15% NaCl + 0.4% $Na_4P_2O_7$ + 0.6% $K_4P_2O_7$. The average drip loss for steaks from top rounds injected with the above solutions was (1) -0.95, (2) -1.5, and (3) -0.1. Statistical analysis of the data from this experiment is presented in Table 10. Tukeys' test (Snedecor 1956) was used to determine which of the treatments were significantly different. The results of this test indicate that the

* sodium Tripolyphospate

Table 10. Analysis of Variance, Average Drip Loss Difference Between Control and Treated Steaks from Top Rounds Injected with 15.0% NaCl + Mixed Polyphosphate Solutions

Source	d.f.	Mean square	F
Total	11		
Treatment	2	1.94	17.64**
Steak	3	0.09	-
T x St	6	.11	

**P<.01

salt-pyrophosphate-hexametaphosphate was the most effective. The least effective was the salt-pyrophosphate combination. When these results are compared with the previous ones, it appears that there is a synergistic effect when the salt-combination phosphate solution is injected in top rounds to prevent drip during the fresh display period.

Principal Experiment: This experiment was undertaken to determine the effect of carcass grade, location of the steak, and fresh display vs. freezing and thawing when the meat was injected with a solution of 15.0% NaCl + 1.0% $Na_4P_2O_7$ + 1.0% $(NaPO_3)_6$. The injection procedures and the post-injection holding time were those established in the preliminary investigations.

The summary of the percent drip loss and the analysis of variance for the fresh display phase are presented in Tables 11 and 12 respectively. Carcass grade appears to significantly influence the amount of fluid lost from steaks during storage. The overall average percent weight loss for each grade was the following: U. S. Standard, 0.47; U. S. Good, 0.67; and U. S. Choice, 0.64. The injected steaks, regardless of grade, retained more fluid within the meat than the controls (Table 11). However, the percent weight loss was influenced by the type of steak (Table 12). The top round steaks tended to lose more weight than the bottom round steaks, while the loin strip steaks lost less than the other two types of steaks.

Freezing and thawing appear to have a great influence on the different variables in these studies; particularly when the

Table 11. Top Round, Bottom Round, and Loin Strip Steaks from Cuts Injected with a Solution of 15.0% NaCl + 1.0% $Na_4P_2O_7$ + 1.0% $(NaPO_3)_6$. Steaks Held Fresh.

	Average Percent Total Drip Loss, All Four Steaks, Each Animal					
	Top round		Bottom round		Loin strip	
	Treated	Control	Treated	Control	Treated	Control
U. S. Choice						
Animal 1	0.64	1.05	0.63	0.76	0.32	0.54
Animal 2	.51	1.25	.44	.59	.36	.54
Average	.58	1.15	.54	.68	.34	.54
U.S. Good						
Animal 1	.66	.92	.61	.83	.39	.60
Animal 2	.78	.92	.67	.96	.37	.53
Average	.72	.92	.64	.90	.38	.57
U. S. Standard						
Animal 1	.41	.72	.41	.67	.40	.55
Animal 2	.45	.54	.32	.47	.39	.54
Average	.43	.63	.37	.57	.40	.53

Table 12. Analysis of Variance for Drip Loss of Steaks During Storage at 40°F. (4°C.)

Source	d.f.	Mean square	F
Total	143		
Grade	2	0.511	12.17**
Animal within grade	3	0.042	1.62
Treatment within grade	3	0.770	59.23**
Steak within grade	6	0.508	16.39**
A x St within grade	6	0.031	1.19
A x T within grade	3	0.013	-
T x St within grade	6	0.075	2.88
A x T x St within grade	6	0.026	1.00
Error	108	0.026	

**P<.01

analysis of variance for drip loss of steaks frozen and thawed (Table 14) is compared to the analysis of variance for drip loss of steaks during storage at 40°F (4°C.) (Table 12). These data suggest that freezing and thawing minimizes the differences among grades, and at the same time increases the differences in the meat from carcasses within the same grade (Table 13). These effects are further exemplified by the non-significant difference among steaks from animals within the same grade (Table 14). However, the injected steaks lost less fluid than the controls during thawing (Table 13).

Table 13. Top Round, Bottom Round, and Loin Strip Steaks from Cuts Injected with a Solution of 15% NaCl + 1% $Na_4P_2O_7$ + 1% $(NaPO_3)_6$. Steaks Frozen and Thawed

	Average Percent Total Drip Loss, All Four Steaks, Each Animal					
	Top round		Bottom round		Loin strip	
	Treated	Control	Treated	Control	Treated	Control
U. S. Choice						
Animal 1	1.65	2.99	2.56	4.82	0.42	3.11
Animal 2	1.73	4.33	1.47	2.22	.47	2.44
Average	1.69	3.66	2.02	3.52	.45	2.78
U. S. Good						
Animal 1	1.75	2.86	1.76	2.57	.87	4.16
Animal 2	2.27	3.19	2.66	4.95	.37	2.41
Average	2.01	3.03	2.21	3.76	.62	3.28
U. S. Standard						
Animal 1	1.62	3.00	1.82	3.01	.65	2.08
Animal 2	.96	1.96	1.31	1.58	.33	.98
Average	1.29	2.48	1.57	2.30	.49	1.53

Table 15 contains a summary of the influence of the salt-pyrophosphate-hexametaphosphate injection on the drip loss of the fresh, and the frozen and thawed steaks within each grade. These data indicate that all the frozen and thawed steaks lost more fluid than the fresh steaks. Between grades, the steaks from the U. S. Standard carcasses lost the least amount of weight. Among the steaks from each grade, the fresh displayed top rounds had more drip loss than the other two types of steaks. However, there appears to be no pattern of difference between

Table 14. Analysis of Variance for Drip Loss of Steaks Frozen and Thawed

Source	d.f.	Mean square	F
Total	143		
Grade	2	10.78	2.59
Animal within grade	3	4.17	10.69**
Treatment within grade	3	30.92	53.31**
Steaks within grade	6	5.08	1.05
A x St within grade	6	4.86	12.46**
A x T within grade	3	0.58	1.49
T x St within grade	6	1.24	
A x T x St within grade	6	1.37	3.51**
Error	108	0.39	

**P<.01

Table 15. Summary Table, Combining Table 11 and Table 13

	Top round		Bottom round		Loin strip	
	Treated	Control	Treated	Control	Treated	Control
Held fresh						
U.S. Choice	0.58	1.15	0.54	0.68	0.34	0.54
U.S. Good	.72	.92	.64	.90	.38	.57
U.S. Standard	.43	.63	.37	.57	.40	.53
Frozen and thawed						
U.S. Choice	1.69	3.66	2.02	3.52	.45	2.78
U.S. Good	2.01	3.03	2.21	3.76	.62	3.28
U.S. Standard	1.29	2.48	1.57	2.30	.49	1.53

the frozen steaks from the three quality grades. One of the reasons for difference between the results of the fresh and frozen steaks is the increased variation within each type of steak due to freezing. Without exception, the coefficient of variation was higher within each type of frozen steak than the corresponding fresh steak (Table 16). The injection treatment did appear to decrease the variation among the fresh

Table 16. Top Round, Bottom Round, and Loin Strip Steaks from Cuts Injected with a Solution of 15.0% NaCl + 1.0% $Na_4P_2O_7$ + 1.0% $(Na_3PO_3)_6$. Steaks Held Fresh or Frozen and Thawed. Coefficients of Variation

Method of Handling	Type of Steak					
	Top Round		Bottom Round		Loin Strip	
	Treated	Control	Treated	Control	Treated	Control
Fresh	0.56% ± .18 (32.14%)	0.90% ± .26 (28.89%)	0.51% ± .06 (11.75%)	0.72% ± .27 (37.50%)	0.32% ± .07 (21.88%)	0.54% ± .13 (24.07%)
Frozen & Thawed	1.66% ± .59 (35.54%)	3.06% ± .97 (31.70%)	1.93% ± .66 (34.20%)	3.19% ± 1.42 (44.51%)	0.52% ± .27 (51.92%)	2.52% ± .83 (32.94%)

and the frozen bottom round steaks. This pattern, however, does not occur among the other two types of steaks handled under the same conditions.

Nitrogen loss in the fluid was collected on steaks from one U.S. Standard and one U.S. Good carcass (Table 17). These data show that the quantity of nitrogen lost during either fresh display or thawing is decreased by the injection treatment.

Table 17. Nitrogen Lost in Drip Fluid from Top Round, Bottom Round, and Loin Strip Steaks Held Fresh or Frozen and Thawed

	Micrograms N per gram of steak lost in drip fluid	
	Fresh	Frozen
U.S. Good Grade		
Top round		
Control	79.9	-
Treated	54.2	-
Bottom round		
Control	85.0	400.2
Treated	53.5	182.5
Strip		
Control	56.1	608.4
Treated	13.4	12.1
U.S. Standard Grade		
Top round		
Control	72.0	407.4
Treated	31.2	156.6
Bottom round		
Control	87.6	632.1
Treated	79.9	222.6
Strip		
Control	23.5	100.5
Treated	18.7	79.8

SUMMARY

These experiments were undertaken to investigate (1) some of the factors associated with drip loss in packaged meat and (2) methods of applying chemical treatments to meat for decreasing drip loss.

Steaks from beef carcasses grading U. S. Choice, U. S. Good, U. S. Standard, and U. S. Commercial were used in the different experiments. The chemical treatments were aqueous solutions of Food Grade salt and/or phosphates applied to the meat to give a 3.0% increase in weight.

Freezing increases the amount of fluid loss, regardless of the type of steak (top round, bottom round, or loin) and the method of applying the chemical treatment. This loss can be decreased by lowering the freezing temperature from -10°F. (-23°C.) to -40°F (-40°C.). Carcass grade also affected drip loss of fresh cut steaks with those from U. S. Standard carcasses losing less than ones from U. S. Choice and U. S. Good carcasses.

Method of applying the chemical treatment, as well as the composition of the treatment solution, determines the extent of the improvement in weight loss. Steaks dipped in salt-phosphate solutions had less fluid loss than corresponding steaks from injected cuts. However, the data indicate that different steaks do not respond in the same manner to the two application methods. When top round steaks were dipped, frozen, and then thawed, the amount of drip was decreased by 80.5%; while those from injected meat showed an improvement of 45.8%. Conversely, loin steaks handled in the same manner retained 37.5% more fluid when dipped, but the retention was improved to 80.7% when they were injected.

These data indicated that the salt concentration and polyphosphates in the injection solution determine the degree of improvement in drip loss. Apparently a salt concentration of 15.0% or above is necessary for optimum results. In addition, a synergistic effect occurs when the 15.0% salt solution contains 1.0% tetrasodium pyrophosphate and 1.0% sodium hexametaphosphate.

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