IMPROVEMENT OF MUSCLE PROTEIN FUNCTIONALITY AND EVALUATION OF SODIUM REDUCTION POSSIBILITY BY COMBINING CRUST-FREEZE-AIR-CHILLING AND COLD-BATTER-MINCING TECHNOLOGIES

By

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ABSTRACT

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Combined effects of crust-freeze-air-chilling (CFAC) and cold-batter-mincing (CM) technologies were evaluated for the improvement of meat protein functionality, and sodium reduction possibility. In study I, hot-boned (HB) turkey breasts were subjected to CM, or to CFAC and CM, and meat quality, and protein functionality parameters were compared to those of the control treatment (cold-boned minced traditionally (CB-T)). HB-CFAC treatments had a higher processing rate than CB-T (chilled by water immersion chilling (WIC), due to the lower chilling times (1 – 1.5 h for CFAC vs 5.5 h WIC). HB-CFAC breast showed higher pH, lower R-value, higher fragmentation index, and similar sarcomere length than CB. CB-T meat was minced at ~10ºC, while HB-CFAC was minced at ~2ºC, all for 7 min. After cooking the minced batter, higher cooking yield and stress values were found in HB-CFAC gels than in CB gels. In study II, CB-T and HB-CFAC batters were minced for 27 min, at two sodium levels (1% or 2.0% table salt). During the first 12 min, the temperature of HB-¼CFAC batter was significantly lower than that of CB-T. Higher protein extraction values were seen on 2% salt HB-¼CFAC batters compared to 1% and 2% salt CB batters when minced for less than 24 min. Stress values of 1% salt HB-CFAC gels were similar to those of CB-T 2% salt, higher than CB-T 1%, but lower than HB-CFAC 2%. In Scanning Electron Microscope images, HB-CFAC cold minced batter proteins seemed to have more protein-coated fat particles, and less denaturation than those of post-rigor batters.

To my beloved parents, for teaching me
the value of determination and hard work.
To my sisters, my aunt, and my grandma,
whose courage is always an inspiration.

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KEY TO ABBREVIATIONS

HB	Hot-boning
CFCA	Crust-freeze-air-chilling
CB	Cold-boning
¼ CFAC	Crust-freeze-air-chilling in quarter portions
WIC	Water immersion chilling
PR	Pre-rigor state
CM	Cold-batter mincing
RTE	Ready to eat
WHC	Water holding capacity
CO_2	Chilled with CO_2
MT	Minced-traditionally
NC	No-chilling

CHAPTER I: INTRODUCTION

1.1 Problem Statement

Pre-rigor (PR) or hot-boned (HB) meat has been reported to have superior quality over chill-boned (CB) meat (Claus and Sorheim, 2006; Sorheim et al., 2006; Dibble, 1993; Cuthbertson, 1980; Kastner, 1977). Froning and Neelakantam (1971) reported that batter made with pre-rigor muscle exhibited higher emulsifying capacity and stability than the batter made with post-rigor muscle.

Additionally, several authors have reported some benefits derived from using HB, such as energy saving, high throughput, improved processing yield, and reduced chilling time/space (McPhail, 1995; Lyon and Hamm, 1986; Troy, 2006). These may represent an advantage for processors compared to the current CB. However, HB meat may result in lower texture quality, lower juiciness score, and irregular shape of final products, if not processed immediately and appropriately (Seabra, 2001; Thomas, 2007). Furthermore, the HB technique has not been adopted in the poultry industry, mainly due to the difficulty synchronizing the slaughter and boning lines, in addition to other issues, such as stricter hygiene and temperature control, facility modification or extension, and employee training (Troy, 2006; Pisula and Tyburcy, 1996).

Currently the estimated average intake of sodium in the US is 4000 mg/day, from which about 20% is believed to come from processed meats (Havas, 2004). This is one of the reasons why processed meats are believed by consumers to have adverse health effects. The meat industry thus faces the challenge to provide reduced-sodium products to consumers; nevertheless, these have been linked to reduced acceptability in texture, flavor, yield, and shelf life. A better understanding on how HB meat will behave under different processing conditions is needed to evaluate its potential in the meat industry.

Crust freeze-air chilling (CFAC) is a technique that reduces meat temperature at a high chilling rate causing the freezing of the meat surface. This method, depending on the meat size, temperature, and air speed, can take less than an hour to achieve the desired internal temperature, which can reduce issues in processing (Herbert, 1980). Regarding cold mincing (CM), Bard (1965) reported that protein extraction was dramatically increased when CM was used, compared to mincing at temperatures higher than 2^{o}C.

Raw meat quality indicators (pH, R-value, etc.), and meat batter properties (pH, batter temperature, protein solubility), both can be used to predict the efficacy of processing technology and subsequent quality of finished meat products.

Therefore, the objectives of this research were:

a) To evaluate the physicochemical properties of raw meat before and after chilling
b) To assess the physicochemical properties of meat batter during mincing at different temperatures, times, and salt levels.
c) To determine the impact of boning-time, chilling conditions, batter-mincing temperature/time, and salt content on protein functionality of turkey breast gels.

In study I, different combinations of HB, CFAC, and CM were used to evaluate the efficacy of chilling time on quality of raw meats, meat batters, and cooked gels. Raw meat quality was assessed using pH, R-value, sarcomere length, and fragmentation index before and after chilling, whereas the quality of meat batter and cooked protein gel was evaluated using batter pH, cooking yield, and stress/strain values for gels.

In study II, four batters were prepared using traditional mincing technology with CB breasts or cold mincing technology with HB-¼CFAC breasts, which were selected based on the results of study I, at 2% or 1% sodium levels. Batter quality, and protein functionality were evaluated.

CHAPTER II: LITERATURE REVIEW

2.1 Turkey meat products

Turkey meat demand has been increasing for over 20 years, which has triggered changes in the poultry processing industry, the meat industry, the scope of turkey products available, and consumer preferences. The trend of poultry products being commercialized, moved from live and whole birds in the early 1900's, to cut-ups and further processing in the present years. The latter combined represent over 70% of recent market share. (Figure 2.1.1) (Barbut, 2002).

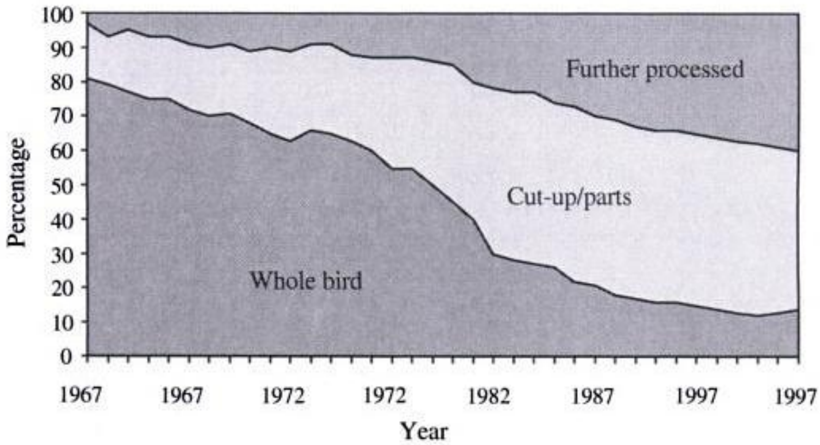


Figure 2.1.1 Poultry products market share

Further processed, ready-to-eat (RTE) turkey products are considered convenient, tasty, nutritious and generally healthier than pork or beef products. These can include deli meats, turkey-bacon, and comminuted products like bologna and hot-dogs, as well as many others.

These products vary as much in their manufacturing as they do in flavor and appearance. Each of them requires certain specific conditions and processes to achieve their desired characteristics. Comminuted meats share a similar basic technology that impact sensory attributes. These products have a long history of using meat of less commercial value, however due to its convenience and increase in popularity new processed products have been developed to meet the different market demands.

2.1.1 Emulsified products (meat gels)

Comminuted products, depending on the degree of particle reduction, can be coarse or finely ground. The latter, also referred to as emulsified, can yield a wide variety of commercial products to cover multiple niches depending on the quality, labeling demands (low fat, low sodium, etc.), price-range, convenience, etc. (Mead, 2002). Finely-ground products can also be divided into two main groups: “cold emulsions” and “hot emulsions”, where significant differences in processing (see Appendix 1) yield either sliceable or spreadable products, respectively (Toldrá 2010). According to Hoogenkamp (2005), a raw meat emulsion (cold emulsion) can be described as dispersion, and under thermal conditions this changes into a gel. The most typical meat gel products are frankfurters, bologna, and lunch or deli meats. Common ingredients include salt, nitrate/nitrite, erythorbate, phosphates, starch and non-starch binders, proteins, sugar, and seasonings (Tarté, 2009). One of the main characteristics of these products is their homogeneous structure resulting from the extensive comminution and uniform gelation. The process by which finely-ground meat structure is formed has been studied for several years and two theories, the emulsion and the physical entrapment, are most accepted. However, there is still a lot of controversy with knowledge gaps.

2.1.2 Commercial processing of meat gel products

Meat processing can be started at animal slaughter or with raw meats already prepared (fresh, chilled, frozen, mechanically separated meats), depending on the manufacturer. Processors now have an extensive range of equipment options to better fulfill their needs when performing the two main comminuting steps, grinding and chopping. For mincing, most machines fall into two basic types, mixers (screw or paddle) and bowl choppers (with or w/o vacuum) (Owens et al 2010; Varnam et al 1995; Toldrá 2010). Alternatively, co-extrusion has been used to improve consistency, efficiency, automation and adaptability, as well as to simultaneously produce the product in its casing (Hoogenkamp, 2005).

Some authors define the main processing stages differently, but the core concepts are similar and can be classified as follows according to Owens (2010):

- *Preblending*
- *Protein extraction and swelling*
- *Emulsion formation and fat encapsulation*
- *Formation of a heat-set gel*

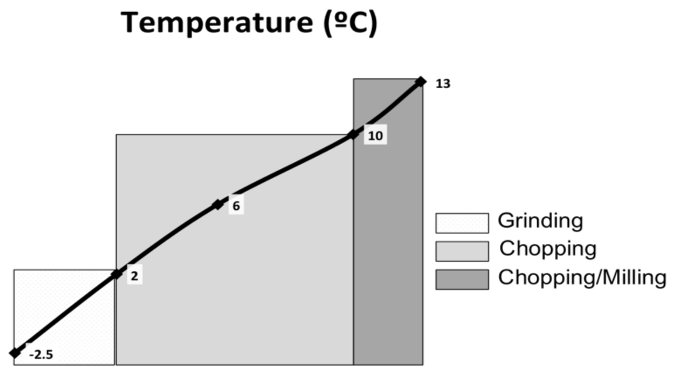


Figure 2.1.2.1 Typical temperature profiles for meat batters during emulsification

Preblending. It is also referred to as lean fragmentation or grinding, which is the first particle reduction point in the comminution process; it is usually done in a screw or paddle mixer. During pre-blending, coarse ground trimmings are formed where fiber bundles are separated, myofibrils are liberated, and in some cases salt or curing salts are added to further increase protein extraction (Owens 2010; Toldrá 2010).

Protein extraction and swelling. The three major groups of proteins in meat are: Sarcoplasmic (water soluble), Myofibrillar (myosin and actin; salt soluble), and Stromal (collagen and elastin; insoluble). Myofibrillar porteins contribute to meat batter stability, whereas stromal proteins at high levels can be detrimental (Barbut, 1995). Proteins are further extracted and solubilized in this stage by the action of the bowl chopper in presence of water, salt and phosphates. Both salt and phosphate play a major role in protein swelling and improvement of water holding capacity with a high pH by phosphate. A colloidal structure is formed where protein-water interactions have an important function in forming the meat batter/emulsion (Owens 2010, Hoogenkamp 2005).

Emulsion formation and fat encapsulation. Homogenization and fat particle reduction continues and solubilized proteins surround fine fat particles during the stage of emulsion. Hydrophobic portions of myofibrillar proteins orient towards the lipid droplets, and hydrophilic ones towards the water phase. Protein-fat interactions play a major role during this stage however the mechanism responsible for holding the fat within the product is still debated. According to the emulsion theory, fat is stabilized in the meat batter by the formation of an interfacial protein film around the small fat globules, whereas the physical entrapment theory suggests that the fat droplets are entrapped within the three-dimensional matrix of the protein, thus stabilizing the gel. Both theories have been supported with micrographs (figure 2.1.2.1), suggesting the existence of both types of interactions (Barbut, 1995; Hoogenkamp 2010; Varnam 1995). Both protein extraction, and emulsion formation take place during the mincing step, typically in a bowl chopper. Regardless of the model, the presence of protein-fat interactions during comminution is undeniable as well as the importance of maintaining protein functionality during this stage.

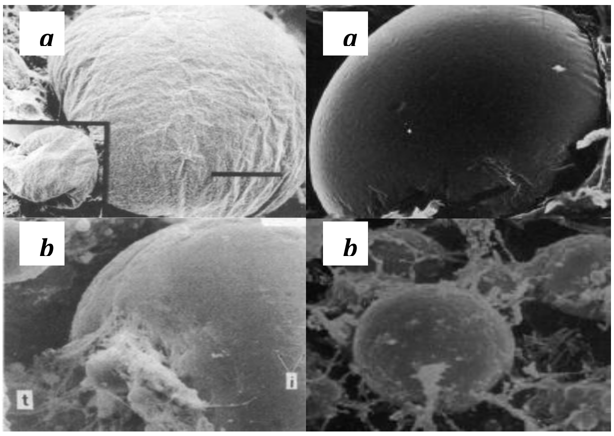


Figure 2.1.2.2. Emulsion theory *a, a'*, and physical entrapment theory *b, b'*

Formation of a heat-set gel. Products are typically heated to an internal temperature of 68.3ºC to 73.9 ºC to denature proteins. The thermally induced events include conformational changes in the proteins, exposure of hydrophobic groups, and gelation. Collagen transforms into gelatin in the presence of heat and binds some water and fats. The three-dimensional matrix formed by the cross-linking of proteins immobilizes fat and water, which is irreversible. Products are then subjected to a rapid temperature reduction and cool storage (Owens 2010, Varnam 1995, Toldrá 2010).

2.1.3 Processing defects of meat gel products

Variations in the processing conditions can render different types of defects, from microbiological to organoleptic, being fragile, grainy, rubbery or tough texture the most common of the latter. Fat pockets, fat rendering and fat separation are also undesirable defects, occurring during comminution, that emerge after cooking (Owens 2010). The use of novel technologies may help processors target some of these defects at the same time.

2.2 Novelties in processing

2.2.1 Hot boning/Pre-rigor

Hot-boning (HB) is the process of muscle removal from an animal carcass before its internal temperature drops significantly and before rigor mortis develops. Several authors have reported many advantages of the processing such as energy saving, high throughput, improved processing yield, and reduced chilling time/space (McPhail, 1995; Lyon and Hamm, 1986; Troy, 2006). The HB processing provides a favorable choice over the traditional CB processing. However, early deboning is typically associated with toughness in the finished products when not processed immediately. (Seabra, 2001). Still the HB meat has been reported to have superior quality over the CB meat (Sorheim et al., 2006; Dibble, 1993; Cuthbertson, 1980; Kastner, 1977). It has been reported by many researchers that more salt-soluble proteins are extracted in pre-rigor muscle compared to post-rigor muscle (Saffle and

Galbreath, 1964; Bernthal et al., 1989; Claus and Sorheim, 2006). The hot boning technique, however, has not been fully adopted in the meat industry mainly due to synchronizing issues (hot-boning line is faster than the further processing line), safety problems (fast microbial growth in hot/warm muscles), and extra cost (initial investment, facility modification, employee training, etc.) (Troy, 2006; Pisula and Tyburcy, 1996). At the industrial scale, HB has been further challenged because poultry muscles have to be obtained and processed no later than 30 min after slaughter due to a rapid onset of rigor mortis (Aberle et al., 2001), which can be difficult when dealing with higher carcass volume.

2.2.2 Crust-freeze –air-chilling

Crust-freeze-air-chilling is a technique that differs from a traditional air chilling in the use of sub-zero temperatures for a rapid chilling, resulting in surface freezing. It is expected for the meat to achieve a desirable texture for slicing, and for HB meat in particular, to have an ideal temperature so that it can be processed with a flexible schedule and place. Its use in the meat industry is relatively new, and research has not been conducted enough for the application of the technology. Conventional air chilling, however, has been widely researched and used in the poultry industry especially in European community, showing benefits on quality improvement, minimal water usage, reduced labor, and no chlorine use (Jeong et al, 2011). The conventional air chilling, however, takes from two to several hours to achieve the desired internal temperature, depending on the size of carcasses or muscles. In beef, the cooling times are relatively longer (> 15 h) than poultry (1 – 2 h) (Herbert, 1980; Jeong et al., 2011). The success of the HB method relies on good hygiene, fast chilling for an automated system, and maintaining of the superior quality (James, 2002). In Denmark, the hot-boning of pork, followed by air chilling (-25 to -30 ºC) has been practiced, allowing fast processing with the reduction of surface temperature to -2ºC in 80 min (Hermansen, 1987). Based on the results, the combination of hot-boning and crust-freeze-air-chilling appears to present a potential technique to rapidly chill poultry carcasses and maintain the high quality of HB meat.

2.2.3 Cold Mincing

Cold-batter mincing (mincing at sub-zero temperatures for a long period of time) is an emerging technology, which is thought to improve protein functionality and gel forming ability. Bard (1965) reported that protein extraction dramatically increased in the range of -5 to 2^{o}C compared to the protein extraction at the temperatures higher than 2^{o}C. The combination of HB-CFAC and cold-batter mincing shows to have 4 major advantages: 1) Increased processing efficacy due to the rapid meat turnover, 2) Reduced synchronizing issues due to the rapid chilling, 3) No issues of muscle thawing and thaw-rigor contraction and 4) Production of pre rigor-quality meat products.

2.3 Factors affecting meat gels

2.3.1 Effect of raw meat quality

Low muscle pH is associated with low water-holding capacity, due to structure alterations and reduced charges in muscle proteins (Guerrero-Legorreta, 2010). Once an animal is slaughtered, biochemical changes occur in the muscle that causes rigor mortis to develop along with a pH drop. The decline of pH is a result of lactic acid accumulation in the muscle when oxygen is not available. The rapid chilling of HB muscle can minimize the postmortem change in the muscle and the loss of high quality of HB meats. Bernthal (1989) reported that HB minced meat resulted in higher amounts of extracted protein and higher water holding capacity (WHC) when compared to the results from CB minced batter. Meat batter made with HB meat exhibited both higher emulsifying capacity and emulsion stability than that of CB muscle (Froning and Neelakantam, 1971; Hamm, 1982). Wyche and Goodwin (1974) reported a higher cooking yield in hot-cut broiler than in the chill-cuts.

2.3.2 Effect of salt content

In sausage mincing, raw meats are chopped with salt (NaCl) to extract tacky and adhesive muscle proteins. The salt in processed meats not only contributes to flavor enhancement and shelf life extension, but also plays a major role in enhancing protein functionality. As a result, salt reduction without food quality loss is a significant technical problem.

2.3.3 Effect of mincing temperature

Brown and Toledo (1975) recommended that batter-mincing temperature should not be higher than 15°C at the end of chopping for a good quality of protein extraction. Upon reaching over 16°C, both water and fat are released from the batter, which resulted in quality loss of finished products (Deng et al., 1976).

Comparing five temperatures from -3.9 to 23.9°C during a 6 min paste mincing period, Gillett et al (1977) reported that the optimum mincing temperature for protein extraction was 7.2ºC. Conversely, Hamm (1966) stated that no major changes occurred in chemical-colloidal or binding properties of protein in the mincing temperatures below 30°C. When salted pre-rigor meats were ground with solid carbon dioxide, Sorheim et al. (2006) observed that the pre-rigor patty had higher pH, lower cooking loss, and firmer texture than those of post-rigor controls

2.3.4 Effect of mincing time

A loss of protein functionality, due to over-chopping, is likely associated with irreversible protein denaturation. However, Bard (1965) reported that the extraction of salt-soluble proteins from post-rigor meat increased proportionally as the extraction time was extended up to 15 h, and that muscle protein extraction from pre-rigor meat was greater at 15 min mincing than that from post-rigor muscle minced for 15 h.

CHAPTER III: EFFECT OF COLD-BATTER MINCING, HOT-BONING AND CRUST-FREEZE-AIR CHILLING ON PROCESSING TIME, AND QUALITY OF TURKEY BREAST GELS

3.1 Abstract

The purpose of this study was to evaluate the combined effects of turkey hot-boning and cold-batter mincing technology on throughput rate, and meat quality. For each of 3 replications, 15 turkeys were slaughtered and eviscerated. Three of the eviscerated carcasses were randomly assigned to water immersion chilling (WIC) for chill-boning (CB), while the remaining were immediately hot-boned (HB), half of which were used without chilling, while the remaining were subject to crust-freezing air chilling (CFAC) in an air freezing room (–12°C/1.0 m/s) without (HB-CFAC) or with ¼-sectioning (HB-¼CFAC). CB and HB breasts were then minced using one of 5 mincing treatments: 1) chill-boned/ mincing traditionally (CB-T), 2) hot-boned/mincing with no chilling (HB-NC), 3) hot-boned/mincing with CO_2 (HB-CO_2), 4) hot-boned/mincing after crust-freezing air chill (HB-CFAC), and 5) hot-boned/mincing after ¼crust-freezing air chill (HB-¼CFAC). The traditional WIC took an average of 5.5 h to reduce the breast temperature to 4°C, while HB-CFAC and HB-¼CFAC took 1.5 and 1.0 h, respectively. The breast of HB-CFAC and HB-¼CFAC showed significantly higher pH (6.0 – 6.1), higher fragmentation index (FI, 196 – 198) and lower R-value (1.0 – 1.1) ($P < 0.05$) than those of chill-boned controls. No significant differences ($P > 0.05$) in sarcomere length were seen between CB-T and HB-CFAC fillets regardless of ¼sectioning. When muscle was minced, the batter pH (5.9) of CB-T was significantly lower ($P < 0.05$) than those (6.1 – 6.3) of HB-NC, HB-CO_2, and HB-¼CFAC, with the intermediate pH (6.0) seen for the HB-CFAC. When meat batters were cooked, higher cooking yield (90 – 91%) ($P < 0.05$) was found in HB-CFAC, HB-¼CFAC, and HB-CO_2, followed by HB-NC (90%) and finally CB-T (86%). Stress values (47 – 51 kPa) of HB-CFAC gels were significantly higher ($P < 0.05$) than those of CB-T (30 kPa) and HB-NC (36 kPa). A similar trend was found in strain values.

Key words: turkey, hot boning, crust-freezing, cold batter-mincing, protein functionality

3.2 Introduction

Accelerated animal processing is always desirable to meat processors and packers. Hot-boning (**HB**) or pre-rigor process is the removal of muscles from an animal carcass before the body temperature is substantially lower (chilled carcass) and before rigor mortis develops. The HB process has many advantages such as energy savings, high throughput, improved processing yield, and reduced chilling time/space over cold-boning (McPhail, 1995; Lyon and Hamm, 1986; Troy, 2006). In addition, HB muscle produces superior quality meats than chill-boned (**CB**) muscles (Sorheim et al., 2006; Dibble, 1993; Cuthbertson, 1980; Kastner, 1977). When HB muscle was minced, more protein was extracted, and higher water holding capacity was obtained than those of CB muscle (Bernthal et al., 1989). The meat batter made with HB meat exhibited both higher emulsifying capacity and emulsion stability than that of CB muscle (Froning and Neelakantam, 1971; Hamm, 1982). Wyche and Goodwin (1974) reported a higher cooking yield in hot-cut broiler than the chill-cuts.

The hot boning technique, however, has not been fully implemented in the meat industry mainly due to synchronization (the hot-boning line is faster than the further processing line) and safety issues (fast microbial growth in hot/warm muscles). Costs associated with facility modification and employee training might be another influential factor (Troy, 2006; Pisula and Tyburcy, 1996). In poultry processing, the hot-boning has been further challenged because muscles have to be obtained and processed no later than 30 min after slaughter due to a rapid onset of rigor mortis (Aberle et al., 2001).

In sausage mincing, raw meats are chopped with sodium chloride to extract salt-soluble muscle proteins. Brown and Toledo (1975) recommended that mincing temperature should not be higher than 15^{o}C at the end of chopping for a good protein extraction. Above 16^{o}C, water and fat are both released from the batter, which results in quality loss of finished products (Deng et al., 1976).

Comparing five temperatures from -3.9 to 23.9°C during a 6 min mincing period, Gillett et al (1977) reported that the optimum mincing temperature for protein extraction was 7.2°C. Conversely, Hamm (1966) stated that no major changes occurred in chemical-colloidal or binding properties of protein at mincing temperatures below 30°C. When pre-rigor meats were salted and ground with solid carbon dioxide, Sorheim et al. (2006) observed that the resulting patty had higher pH, lower cooking loss, and firmer texture than those of post-rigor controls. Mincing at sub-zero temperatures, thus suggests that protein functionality may be improved; this has been known as cold-mincing in the meat industry and is considered an emerging technology.

Considering the individual advantages of hot-boning, crust-freeze-air chilling, and cold-mincing, may suggest that the combination of these techniques can affect the meat industry in a positive way. Some of the potential benefits of the combined methods are: fewer synchronization issues, no thaw-rigor contraction, higher processing rate and throughput, and the potential for lower sodium formulations to yield high quality products.

Regarding batter mincing at different temperatures and time, Bard (1965) reported three interesting results of protein extraction: 1)The extraction of salt-soluble proteins from post-rigor meat proportionally increased as the extraction time was extended up to 15 h, 2)Protein extraction dramatically increased in the range of -5 to 2°C compared to temperatures higher than 2°C; and 3)Muscle protein extraction from pre-rigor meat in 15 min of mincing was greater than that of post-rigor muscle extracted for 15 h.

The purpose of this study was to evaluate the effect of HB-CFAC on processing time, and the effect of cold-batter mincing on protein functionality of the HB-CFAC gels.

3.3 Materials and methods

3.3.1Turkey slaughter and dressing, carcass chilling, and sample preparation

Three batches of fifteen live Nicolas tom turkeys (16 weeks-old, ~18 kg in live weight) each, were obtained in three different occasions between July and December of 2011 from a farm in north Indiana. Three replications were completed at the end of this study, and a total of forty-five turkeys (fifteen turkeys per batch) were used.

After birds were withdrawn from feed for 12 h and cooped in plastic cages, the birds were transported to the Michigan State University meat and poultry processing laboratory. On the morning of the arrival, the birds were electrically stunned for 6 s (80 mA, 60 Hz, 110 V), and bled for 90 s by severing both carotid artery and jugular vein on one side of the neck. The turkeys were then scalded (59ºC, 120 s), mechanically defeathered (25 s), and manually eviscerated. After washing, carcasses were weighed, and their internal temperatures were recorded from the center of the turkey breast using a digital thermometer/logger (model 800024, Sper Scientific Ltd., Scottsdale, AZ).

In each replication three out of the fifteen carcasses were randomly assigned to one the following treatments (Figure 3.3.1.):

1) Water Immersion Chilling (WIC), cold-boned (CB), and minced traditionally **(CB-T)**
2) Hot-boned, minced at room temperature **(HB-NC)**
3) Hot-boned, minced at sub-zero temperatures with solid CO_2 **(HB-CO_2)**
4) Hot-boned, crust-freeze-air chilled, and minced at sub-zero temperatures (**HB-CFAC)**
5) Hot-boned, crust-freeze-air chilled in quarter portions, and minced at sub-zero temperatures **(HB-¼CFAC)**

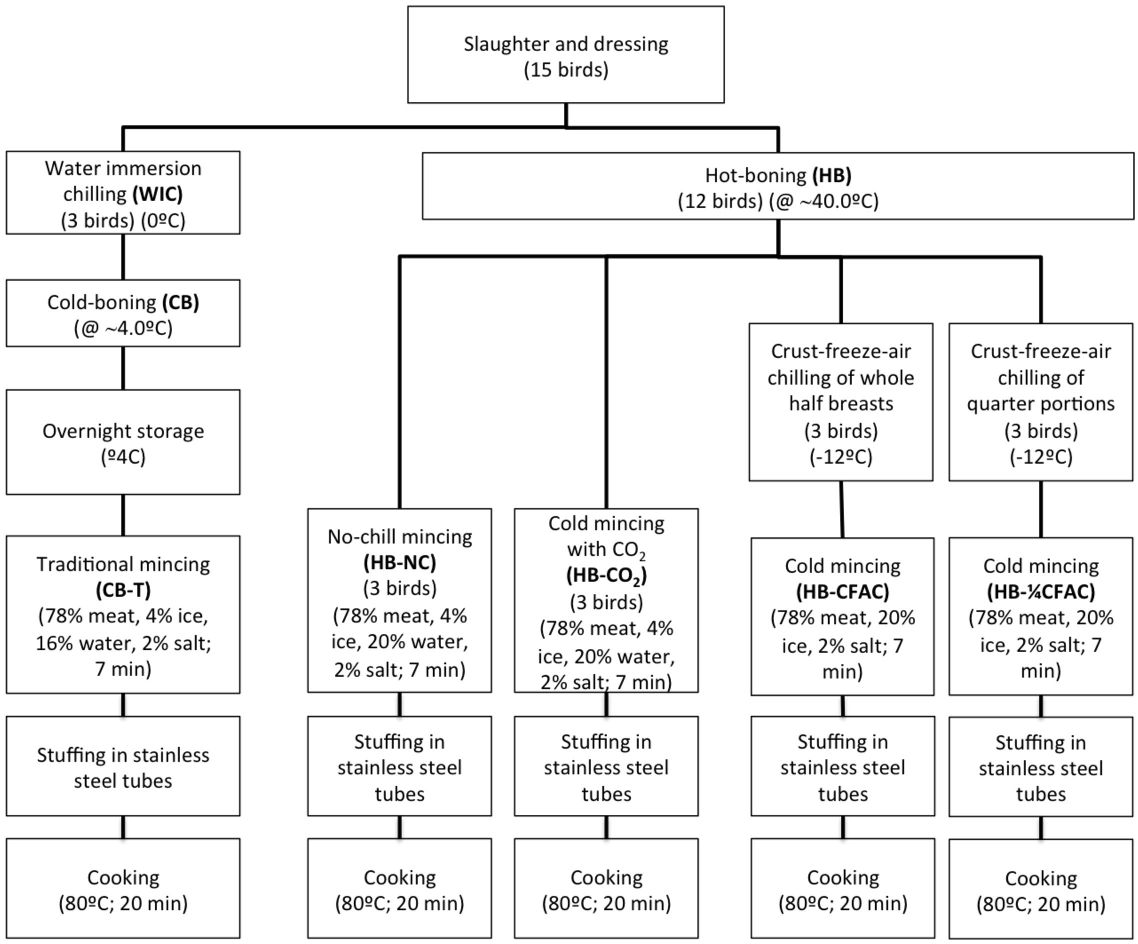


Figure 3.3.1. Process flow for study 1

All three WIC turkeys were chilled in a plastic tank containing a mix of water and ice (~40 L @approximately 0.5ºC) (Figure 3.3.3 A, A') with mechanical agitation (0400–025GV1S portable agitator, Grovhac Inc., Brookfield, WI). The temperature of one representative carcass was measured every five minutes and recorded. The carcasses were taken out of the chilling tank after reaching 4ºC. The carcasses were then cold-boned **(CB)**, and samples were immediately taken (1 cm thickness) from the cranial, medial, and caudal portions (Figure 3.3.2) of the right breasts (three samples per carcass), placed in temperature resistant plastic bags, properly tagged, frozen in liquid nitrogen, and stored in a freezing room (-20.0ºC) for further testing. The left breasts were stored in gallon-size Ziploc bags in a chilling room (4.0ºC) for overnight storage (~16 h).

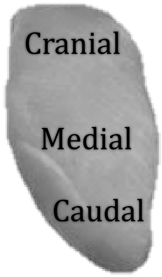


Figure 3.3.2. Graphic representation of turkey breast portions

The remaining twelve birds were hot-boned **(HB)**, and samples from the right breasts were taken and stored, immediately after hot-boning, in the same way as mentioned above. HB-NC and HB-CO_2 breasts were processed immediately as described in the *Breast mincing and gel preparation* section of this chapter. The left HB-CFAC breasts were placed in an air freezing room (~1 m/s, @-12^{o}C) for crust-freeze-air chilling (CFAC) (Figure 3.3.4 B, B'), while left HB-¼CFAC breasts were manually sliced into four portions of similar size (Figure 3.3.3) before CFAC (Figure 3.3.4 C, C').

The temperature of one representative breast was taken every 5 min for each CFAC treatment. The breasts were taken out of the freezing room after reaching an internal temperature of 4ºC. Samples from the frozen meat were then taken and stored in the same fashion as for WIC treatment. The remaining frozen meat was minced directly after chilling.

Figure 3.3.3. Left turkey breast in quarter portions

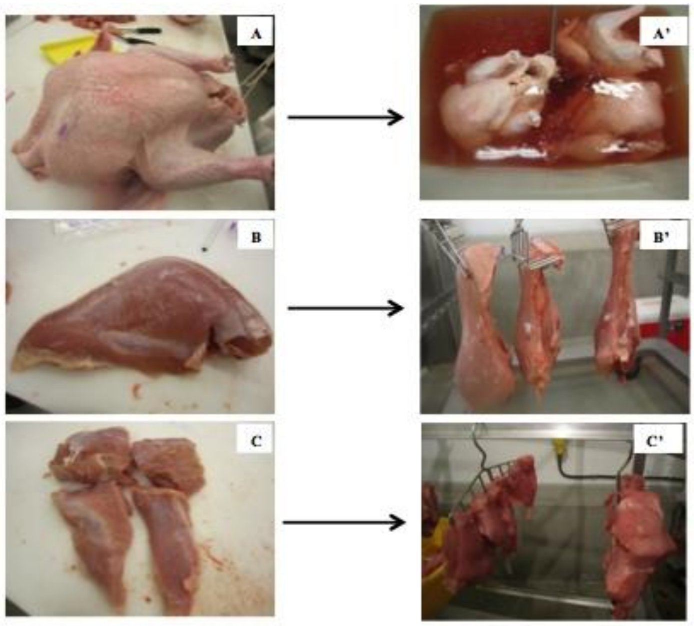


Figure 3.3.4. Water immersion chill (WIC) of whole turkey carcass and crust-freeze-air chill (CFAC) of hot boned (HB) breast with/without ¼ section. A: Whole turkey carcass, A': WIC, B: HB breast half, B': HB/CFAC, C: HB/¼ sectioned breast, C': HB/ ¼ sectioned/CFAC

3.3.2 Breast mincing

All five treatments were minced in a food cutter (256 rpm, Models 84181, Hobart, Troy, OH) in the meat processing lab at Michigan State University. Each batch (~25 Kg) was mixed for 7 min using the following formulations (% from total batch mass):

CB-T: 78% chilled-boned meat, 4% water (25ºC), 16% ice (0ºC), and 2% table salt

HB-NC: 78% hot-boned meat, 20% water (25ºC), and 2% table salt

HB-CO_2: 78% hot-boned meat, 4% water (25ºC), 16% ice (0ºC), 2% table salt, and solid CO_2 (enough to reduce and maintain the temperature around -2ºC)

HB-CFAC: 78% crust-freeze-air chilled whole breasts, 20% ice (0ºC), and 2% salt.

HB-¼CFAC: 78% crust-freeze-air chilled breasts in quarter portions, 20% ice (0ºC), and 2% table salt.

Samples (50 g) of each batter were taken, placed in temperature resistant plastic bags, labeled, and stored in a freezing room (-20ºC) until being tested for pH. Each batter was placed in gallon size Ziploc bags, and stored overnight in a chilling room (4ºC) before gel preparation.

3.3.3 Gel preparation

After mincing, batters were cooked into gels using the method of Jeong et al. (2011). Each treatment batter was stuffed into pre-weighed stainless steel cylindrical tubes, and put into a water bath (model 25, Precision Scientific Co., Chicago, IL) at 80°C for 20 min. After cooking, the tubes were immediately placed in an ice bed (~30 min) to reach room temperature, before being tested for cooking yield and texture.

3.3.4 Sample Testing

The samples for pH determination were measured from the previously frozen medial portions of the right fillets and from frozen batters. The sample preparation followed the procedure used by Sams and Jancky (1986), and done in duplicates for each sample. After storage (-20ºC) the frozen samples were individually placed in new temperature-resistant plastic bags, immersed in liquid nitrogen for further freezing, double wrapped in aluminum foil and paper towel, and pulverized using a hammer. 2.5 g of each powdered sample were homogenized in 25 mL of homogenizing solution (0.005M Iodacetate) for 30 sec. using a benchtop homogenizer. The homogenized samples were let to reach room temperature before determining the pH, which was measured with a pH electrode (model 13-620-631, Fisher Scientific Inc., Houston, TX) attached to a pH meter (Accumet AR15, Fisher Scientific Inc., Pittsburgh, PA).

The ratio of inosine-monophosphate:adenosine-triphosphate (R-value) was assessed as an indicator of adenosine triphosphate (ATP) depletion in the muscle, using the method of Thompson et al. (1987). Previously frozen medial portions of the right fillets were used to determine R-value. After storage (-20ºC) the samples were individually placed in temperature-resistant plastic bags, immersed in liquid nitrogen, double wrapped in aluminum foil and paper towel, and pulverized using a hammer. 3.0 g of powdered sample were placed into a plastic beaker with 20 ml of 1M perchloric acid, and homogenized for 1 min on 60% power using a benchtop homogenizer. The homogenized samples were then filtered through filter paper, and 0.1 ml of the filtrate was transferred to a disposable glass tube, where 4.0 ml of 0.1M phosphate buffer were added. The absorbance of this solution was read at 250 nm (IMP) and 260 nm (ATP), as indicators of Inosine and Adenosine respectively. The following equation was used to get the R-value:

$$\frac{A250}{A260} = R\text{-}value$$

The distance between one Z disk to the next Z disk in a sarcomere (muscle functional unit) is known as sarcomere length; sarcomeres in a striated muscle act as a diffraction that break light into a measureable pattern.

The sarcomere length was measured from the caudal portion of the previously frozen right breasts following Voyle (1971), and Cross et al (1981). The frozen samples were taken out of storage (-20ºC), cut into small cubes (~1 cm^3), and about 10-15 g of the sample were homogenized (@90% power) in 50 ml of iodoacetate solution (0.25M sucrose, 0.002M KCL, 0.005M iodoacetate @4ºC) on an ice bed for about 12s. A drop of homogenate was placed between a slide and a coverslip, and placed onto the stage of the laser stand; the board of the laser stand was place at 100 mm from the top of the slide. Once the laser was on, the slide was moved carefully until a diffraction pattern was seen on the base of the board, the distance between the origin and the first order diffraction band was measured; 10 readings were recorded for each sample in a dark room.

The readings were used in the following equation to get the sarcomere length:

$$\frac{0.6328 * D * \left[\left(\frac{T}{D}\right)^2 + 1\right]^{\frac{1}{2}}}{T} = Sarcomere\ Length$$

0.6328 = Wavelength of the Helium-Neon laser light

D = Distance in mm from specimen to the diffraction screen

T = Distance in mm from the origin to the first order diffraction band

The myofibril fragmentation was measured as and indicator of the degradation of the Z-discs (Fragmentation Index). This was evaluated using Sams (1991) gravimetric method. To obtain the Fragmentation Index (FI), nylon screens (250µm) were cut into a circular, dried for 16 h in a drying oven (100ºC); after drying the screens were handled with nitrile gloves to avoid moisture transfer. The weights of the screens were measured in an analytical balance, and recorded. 4-5 g of previously frozen cranial samples were cut into 2x2 mm cubes, and homogenized in 40ml of cold (4ºC) homogenizing solution (0.25M sucrose, 0.002M KCL, 0.005M iodoacetate @4ºC, pH=7 KOH) using a benchtop homogenizer for about 30 s. The homogenate was vacuum-filtered through the pre-weighted screen and a filter paper, using a Buchner funnel and flask. The screens with the unfiltered sample were dried overnight for about 18 h in a drying oven (102ºC), and then cooled in a desiccator (20 min) before the final weight was recorded. The weight of the dried sample was obtained using the following formula:

$$\frac{Wt_{ds} - Wt_s}{Wt_{ws}} * 1000 = Fragmentation\ Index$$

Wt_{ds}= Weight of dry sample with screen

Wt_s Weight of screen

Wt_{ws}=Weight of wet meat sample

The cooking yield (percentage of the initial weight of the meat batter retained after cooking) was determined by individually weighing the ten tubes used for each treatment, prior to (empty tube and two caps), and after stuffing (stuffed tube and two caps). After cooking and cooling, the purged water was drained off the tubes, and each cooked gel and its cooking tube were dry with paper towels, and weighed together. All weights were recorded and the final cooking yield was determined with the following formula:

$$\frac{Wt_{ad} - Wt_{bs}}{Wt_{st} - Wt_{bs}} * 100 = \%\ Cooking\ yield$$

Wt_{bs}= Weight of tube before stuffing

Wt_{st}= Weight of stuffed tube

Wt_{ap}= Weight of dried drained tube with cooked gel

To determine shear stress and shear strain, as indicators of hardness and elasticity respectively, the cooled cooked gels were cut perpendicularly in 3.0 cm length cylinders after reaching room temperature (25ºC). Styrene disks were glued to the upper and lower bases of the 3.0 cm cylinders using Loctite® Super Glue Liquid. The samples were then milled into a dumbbell shape (10 mm in diameter at the midsection) by using a shaping machine (KCI-24A2, Bodine Electric Co., Raleigh, NC). Each specimen was placed on a viscometer (DV-III Ultra, Brookfield Engineering Laboratories Inc., Middleboro, MA) and twisted at 2.5 rpm. Ten samples were evaluated for each treatment for 3 separate replications. At the breaking point, both shear stress and shear strain were calculated with the recorded torque and elapsed time using the following equations (Hamann, 1983).

$$\frac{Tq * 1582}{100} = Stress$$

$$[(t * 0.2618) - (Tq * 0.0148)] * 0.5724 = Strain$$

t= Time at fracture

Tq= Torque (%)

3.3.5 Statistical Analysis

All experiments were replicated 3 times. Data were evaluated using PASW 18 statistic program (2009) by one-way ANOVA, and a post-hoc analysis was performed with Duncan's multiple range test to evaluate difference among treatments.

3.4 Results and discussion

The carcass temperature after evisceration was 40.5°C ± 2.0, which decreased to 4°C with an average chilling time of 5.5 h in ice slurry chilling (approximately 0.2^{o}C, Figure 3.3.1 A, A'). When breasts were hot-boned (HB) and crust-freeze-air chilled in a freezing room (~1 m/s, @-12^{o}C), the average chilling times were 1 and 1.5 h, for the HBCFAC fillets without (Figure 3.3.1 B, B') and with ¼ sectioning (Figure 3.3.1 C, C'), respectively. Sams (1999) indicated that turkeys take 3 – 6 h to reduce the postmortem carcass temperature to 4^{o}C in WIC, depending on their body size. Sams and McKee (2011) reported that air is 25 times less efficient than water in heat convection, explaining why AC took longer times than WIC for turkey and broiler (James, 2002; Jeong et al., 2011). The heat removal from the food surface is a direct function of the surface heat transfer convection coefficient (*h*), which ranges from 5 W/m$^{2.o}$C for slow-moving air to 500 W/m^{2o}C for agitated water (James, 2003).

The reduction of chilling time from 4 – 6 h (whole carcasses) to 1h (HB fillets) can make the process more efficient, with less synchronization issues, reduced labor, lowered maintenance fee, and minimized chilling space (Kang 2011-personal communication). Additionally, the rapid chilling method may reduce the effects of PSE (pale, soft, and exudative) turkey, which is induced by the combination of high muscle temperature and rapid pH reduction, causing annual losses of over $200 million in the turkey industry (Owens et al., 2000). Alvarado and Sams (2002) also found that product integrity was negatively affected in turkey carcasses when chilling was delayed or conducted slowly.

Turkey breast pH ranged from 6.28 to 6.35 immediately after hot boning (Table 3.4.1), indicating that they were normal glycolyzing breasts (pH > 6.0 at 15 min postmortem) rather than rapid glycolyzing breasts (pH ≤ 5.80), according to Rathgeber et al. (1999). After chilling, the breast pH of 5.5 h WIC lowered to 5.82, which was significantly lower ($P < 0.05$) than those of 1.5 h HB-CFAC (pH 5.99) and 1 h ¼CFAC (pH 6.12) (Table 3.4.1). Owens et al. (2000) indicated that the breast pH (6.09) of normal turkey was higher than that (pH 5.72) of pale turkey at 1.5 h post-mortem. Marsh and Thompson (1958) reported that glycolysis proceeds slowly with ATP depletion in lamb muscle at -5°C, which supports the higher muscle pH seen in turkey breast at -12°C than at 0°C in this study. The combination of early pH decline (0.5–1 h) and high body temperature (~37°C) is detrimental to protein functionality (water holding capacity and texture cohesiveness) and visual appearance (Warris and Brown, 1987; Bendell and Wismer-Pedersen, 1962; Offer, 1991).

R-value (the ratio of inosine:adenosine-containing compounds) of HB breasts ranged from 0.87 to 0.98 (Table 3.4.1). After CFAC, the value increased to 0.99 – 1.08, which is significantly lower ($P < 0.05$) than that (1.31) of WIC fillets, indicating that ATP was less depleted in the AC breasts at -12°C (Table 3.4.1). In accordance with these results, Owens and Sams (1997) reported that the R-value of turkey breasts after 2 h WIC was 0.94, which increased to 1.11 and 1.21, respectively, at 8 and 24 h postmortem. McKee and Sams (1998) indicated that higher R-values were seen in turkeys subjected to water at 40ºC, compared to those in water at 20°C and 0°C, after 15 min and 4 h post-mortem.

Sarcomere length is an indicator of muscle contraction that is correlated with muscle tenderness; longer sarcomeres suggest higher expressed tenderness (Locker, 1960). Muscles that undergo rigor mortis while still attached to the bone, like in WIC, are known to yield higher sarcomere length values when compared to hot-boned muscles (muscles deboned before the development of rigor mortis). Hot-boned muscles have high ATP concentration which makes them prone to muscle fiber shortening during chilling due to the high energy used for muscle contraction. Papa and Fletcher (1988) indicated that muscles had less sarcomere shortening when stored at 16°C, while more shortening was seen at either 0ºC or 40ºC at 2 h post-mortem. Rapid chilling with air at -12°C was reported to induce cold shortening (irreversible contraction of actin and myosin filaments) in broiler carcass with pH values ≥ 6.70 at 15 min post-mortem, although shear force value was reported to be 1.00 kg cm^{-2} lower than those chilled in air at 0°C (Dunn et al., 1995). In this study sarcomere length values for HB-CFAC and WIC (1.8 – 1.84 µm) were not significantly different (P < 0.05) from each other, but were significantly higher than the values obtained (1.24 – 1.32 µm) from HB meat with no chilling (Table 3.4.1). The gravimetric stretch that occurred during hanging of HB-CAFC muscles (Figure 3.4.1C') is a possible explanation to the sarcomere length values found in these treatments, the stretch may have caused a similar effect than the one produced by chilling while muscles are still attached to the bone.

Sarcomere shortening was reported to decrease when breasts were physically stretched (Papa et al., 1989; Janky et al., 1992; Walker et al., 1994). In beef, Simmons et al. (1999) also reported that *longissiumus thoracis* muscle had a significantly lower shear force, when stretched by 20%, than the non-stretched control.

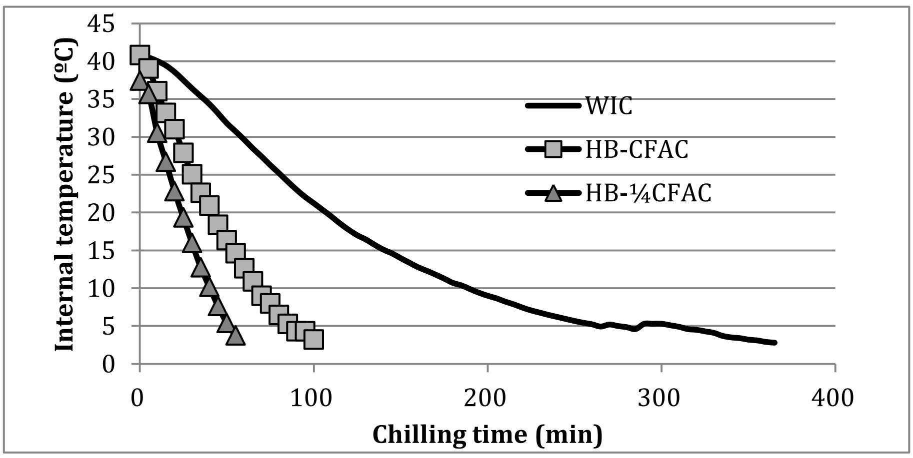


Figure 3.4.1. Temperature change profiles of turkey breast fillets during water immersion chill (WIC), hot-boned/crust-freeze-air-chill (HB-CFAC), and hot-boned/¼ sectioned/crust-freeze-chill (HB-¼CFAC) (n=9)

Fragmentation index is inversely related with the level of muscle aging and/or protein degradation rather than physical tearing of muscle fibers (Birkhold and Sams 1993). The fragmentation index (178.6) of CB fillets was significantly lower than those (193.5 – 200) of HB fillets regardless of CFAC (Table 3.4.1). The low value is expected from the aging that occurred during 5.5 h WIC, whereas the HB and HB-CFAC fillets had almost no or short aging times, respectively. Owens and Sams (1997) reported that fragmentation index was reduced from 186.9 to 164.5 as the harvest of turkey breast was delayed from 2 to 24 h postmortem. Veeramuthu and Sams (1999) showed that both calpain activity and fragmentation index were gradually decreased as broiler carcasses were aged up to 24 h.

Table 3.4.1. pH and R-value (±SEM)[1] of turkey breasts that were chill-boned (CB), hot-boned (HB), or hot-boned/crust freezing air chilled (HB-CFAC)

Parameter	CB-T[2]	HB-NCM[3]	HB-CMCO$_2$[4]	HB-CFCM[5]	HB-¼CFCM[6]
pH-before chill	n/a	6.28 ± 0.14^a	6.25 ± 0.15^a	6.22 ± 0.09^a	6.35 ± 0.13^a
pH-after chill	5.82 ± 0.18^b	n/a	n/a	5.99 ± 0.09^a	6.12 ± 0.16^a
R-value-before chill	n/a	0.97 ± 0.21^a	0.98 ± 0.13^a	0.93 ± 0.10^a	0.87 ± 0.28^a
R-value-after chill	1.31 ± 0.13^a	n/a	n/a	1.08 ± 0.10^b	0.99 ± 0.28^b
Sarcomere length after chill/no chill	1.84 ± 0.11^a	1.24 ± 0.10^b	1.32 ± 0.02^b	1.82 ± 0.08^a	1.85 ± 0.06^a
Fragmentation index-after chill	179 ± 3.07^b	194 ± 7.22^a	200 ± 4.70^a	$196.\pm 7.52^a$	198 ± 18.7^a

[a,b]Means within a row with the same superscripts are not significantly different ($P < 0.05$).
[1]The number of observations in each chilling, n = 10 – 15.
[2]CB-T – chill-boned fillets (after water immersion chilling) for mincing traditionally
[3]HB-NCM –hot-boned fillets for mincing with no chilling
[4]HB-CMCO$_2$ –hot-boned flllets for mincing with CO_2
[5]HB-CFCM–hot boned/crust-freezing air chilled fillets for mincing in cold temperatures
[6]HB-¼CFCM –hot boned/¼ sectioned/crust-freezing air chilled fillets for mincing in cold temperatures

The temperatures of the batters differed between treatments. CB-T started with meat at approximately 2ºC, and after the addition of water and ice, and 7 min of mincing the temperature of the batter reached 10ºC. For HB-NCM, the initial T was close to 40ºC and after mincing it lowered to 25ºC. HB-CO_2 also started with meat at 40ºC, and after the addition of CO_2, and 7 min of mincing, the T was close to -2.0ºC. Both HB-CFAC treatments started with meat at approximately -2.5ºC, and after the addition of ice, and 7 min of mincing a drop of 0.5ºC was observed (Table 3.4.2). The higher temperatures observed during HB-NC mincing may have an impact in WHC due to protein denaturation. It is expected that cold mincing treatments (final T~ -2.0) result is higher cooking yield values.

Table 3.4.2. Temperature changes[1] of meat batters during 7 min mincing of turkey fillets that were chill-boned (CB) or hot-boned/crust-freeze- air chilled with (HB-¼ CFAC)/without (HB-CFAC) ¼ sectioning

Parameter[2]	CB-T	HB-NC	HB-CO_2	HB-CFAC	HB-¼CFAC
Before mincing[2] (raw meats)	2 ± 2^{o}C	40 ± 2^{o}C	40 ± 2^{o}C	-2.5 ± 1^{o}C	-2.5 ± 1^{o}C
After 7 min mincing (batter)	10 ± 1^{o}C	25 ± 1^{o}C	-2.0 ± 1^{o}C	-2.0 ± 0.5^{o}C	-2.0 ± 0.5^{o}C

[1]The number of observations in each chilling/mincing, n = 10 – 15.
[2]Chilling/mincing conditions as in Table 3.4.1.

Upon the completion of batter mincing, the pH (5.87) of CB-T batter was significantly lower (P < 0.05) than those (6.07 – 6.26) of HB-NC, HB-CO_2, and HB-¼CFAC, with the intermediate (pH 6.0) seen for HB-CFAC (Table 3.4.3). Sorheim et al. (2006) reported that the pH of CB beef batter was slightly lower (P < 0.05) than that of HB batter minced with CO_2. When the minced batters were stored at 4^{o}C overnight, the pH (5.90 – 5.92) of CB-T and HB-¼CFAC were significantly lower (P < 0.05) than those (6.06 – 6.10) of HB-WC and HB-CO_2, with the intermediate (5.97) seen for HB-CFAC (Table 3.4.3).

After cooking the resulting gels for CB-T had significantly lower cooking yield values (86.1%) compared to all HB treatments (Table 3.4.3). This can be explained by the lower initial meat pH (Table 3.4.1) in combination to higher mincing temperatures (with HB-CO_2, and both HB-CFAC). No significant differences were observed between HB-NC and HB-CO_2 gel cooking yield values (89.73 and 90.32) suggesting that cold mincing is capable to retain the protein functionality of pre-rigor meat. Both HB-CFAC gels treatments had similar ($p<0.05$) cooking yield to HB-CO_2. Sorheim et al., (2006) reported higher cooking yield (~97%) values in beef patties from pre-rigor/CO_2 chilling than that (88.8%) of post-rigor control.

The texture of cooked gels assessed by torsion test, in which shear stress (a measure of gel strength) and the shear strain at failure (a measure of gel deformability) are correlated with sensory hardness and cohesiveness, respectively (Hamann and Lanier, 1987). The stress values (47.7 – 50.9 kPa) of hot-boned/chilled meat gels (HB-CO_2, HB-CFAC and HB-¼CFAC) were significantly higher ($P < 0.05$) than those (29.6 – 36.0 kPa) of chill-boned or hot-boned/no-chilled meat gels (Table 3.4.3). Similarly, the strain values (1.58 – 1.67) of hot-boned/chilled-meat gels were higher than that (1.21) of chill-boned control, with the intermediate (1.52) seen for the hot-boned/no-chilled.

Table 3.4.3. Cooking yield, stress and strain values (±SEM)[1] of turkey breast gels that were made with breast muscles chill-boned (CB), hot-boned (HB), or hot-boned/crust-freeze-air chilled (HB-CFAC)

Parameter[2]	CB-T	HB-NC	HB-CO_2	HB-CFAC	HB-¼CFAC
Batter pH after mincing	5.87 ±0.18[c]	6.12 ± 0.14[ab]	6.26 ± 0.15[a]	6.00 ± 0.09[bc]	6.07 ± 0.13[ab]
Batter pH after overnight storage	5.90 ± 0.18[b]	6.06 ± 0.21[a]	6.10 ± 0.13[a]	5.97 ± 0.09[ab]	5.92 ± 0.16[b]
Cooking yield (%)	86.14 ± 0.18[c]	89.73 ± 0.21[b]	90.32 ± 0.13[ab]	90.21 ± 0.10[ab]	91.29 ± 0.28[a]
Stress (kPa)	29.56 ± 0.13[b]	36.02 ± 0.10[b]	47.70 ± 0.10[a]	47.98 ± 0.10[a]	50.92 ± 0.28[a]
Strain	1.21 ± 0.10[c]	1.52 ± 0.10[b]	1.67 ± 0.10[a]	1.58 ± 0.10[ab]	1.61 ± 0.10[ab]

[a,b,c] Means within a row with the same superscripts are not significantly different ($P < 0.05$).
[1]The number of observations in each chilling/mincing, n = 10 – 15.
[2]Chilling/mincing conditions as in Table 3.4.1.

In support of these findings in CB gels, Rathgeber et al. (1999) indicated that stress and strain values for normal glycolyzing turkey breast (pH >6.0 at 15 min postmortem) were significantly higher than those of rapid glycolyzing breast (pH ≤ 5.8 at 15 min postmortem). Alvarado and Sams (2004) showed that slow rates of turkey chilling at 30°C resulted in reduced gel strength, greater cook loss, greater lightness (L* value) and lower pH than those of fillets chilled at 0°C. Jeong et al. (2011b) also reported stress (25.6 kPa) and strain (1.3) values from CB broiler breast gels, which are similar to the findings in turkey gels. Delaying of initial carcass chilling reduced both stress and strain values of turkey breast gels, potentially due to low protein extractability for protein to form gels (Rathgeber et al., 1999). The strength of PSE meat gels was reported to 45% of that from normal pork gels in the same protein concentration (Camou and Sebranek, 1991).

The results of this study suggest that the combination of hot-boning and crust-freezing air chill, and cold-mincing on turkey breast provides various advantages such as fast hot-boning process, meat with pre-rigor quality, high cooking yield, and superior protein functionality. Based on these results, the combination of cold-mincing and crust-freezing air chill could be a viable processing method for academic research and industrial application. Additional research like microbial evaluation, sensory analysis, and preliminary trials are required to evaluate how effectively and practically the technology can be further developed and implemented in the meat industry.

3.5 Conclusions

Pre-rigor meat, although superior in protein functionality, has not been largely implemented due to the limits of speed synchronization, excessive refrigeration, and intensive labor (Saffle, 1968). Once meat is hot boned, it is difficult to maintain the pre-rigor condition and hygiene standard unless the meat is processed immediately or frozen. With the combination approach (hot-boning and crust-freezing) in this study, some of the issues associated with synchronizing the processing line appear to be improved, while the cold-mincing helped in maintaining the functional and economical value of hot-boned muscles.

CHAPTER IV: EFFECT OF SODIUM REDUCTION ON COLD-BATTER MINCED, HOT-BONED, ¼-SECTIONED-CRUST-FREEZE-AIR-CHILLED TURKEY BREAST GEL QUALITY

4.1 Abstract

In previous studies, the combination of Crust-freezing air chilling (CFC) and Cold-mincing (CM) during processing showed an improvement of Hot-boned (HB) meat on cooking yield and on sensory quality when compared to the commercial Cold-boning (CB) process, which could be beneficial to overcome the technical issues brought by salt reduction. Therefore the purpose of this research was to evaluate the effect of sodium reduction in turkey gels made out of HB breasts and processed by CFAC in quarter portions, and CM on overall protein functionality. For each replication, two processing methods at two sodium levels were studied. Half of the carcasses were assigned to either WIC or to the HB-¼CFAC process. After chilling HB-¼CFCM fillets had a significantly ($P < 0.05$) higher pH (5.94) and significantly lower R-value (1.19) compared to CB fillets (pH=5.73; R-value=1.32), suggesting less ATP depletion and glycolization, and better protein functionality at that stage. Chilled fillets were traditionally (T) minced (15ºC) for CB-T, and cold minced (-2.5^{o}C) for HB-¼CFCM fillets, each group at 1% and 2% salt. After mincing, the pH of batters showed no significant difference ($P > 0.05$) between the CB-T and the HB-¼CFCM batters after 6 min in 2% salt, whereas for 1% salt batters, significantly lower pH was seen in HB-¼CFCM after 15 min mincing, suggesting similar protein functionality when minced for less than that time. Additionally HB-¼CFCM batter had more solubilized protein than CB batter after min 9 for the 2% treatments, and after min 12 for those with 1% salt. Stress values in 2% salt HB-¼CFAC gels were higher ($P < 0.05$) than in 1 and 2% salt CB gels, with intermediate values seen for 1% salt HB-¼CFAC gels. In scanning electron microscope (SEM) images, pre-rigor batter appears to have more air pockets, less protein aggregation, and fat particles coated with more protein than the SEM of post-rigor batters.

Key words: Sodium reduction, hot-boning, crust-freezing, cold mincing, protein functionality

4.2 Introduction

Many Americans are consuming excessive amounts of salt, which can lead to negative health impacts. The largest portion (77%) of salt in American diet comes from processed products and restaurant foods (Mattes and Donnelly, 1991). As a result, meat processors are challenged on how sodium levels can be reduced in their products. Hot-boning or pre-rigor processing has been known to generate superior quality to chill-boning for raw and processed meat products (Cuthbertson, 1980; Kastner, 1977). Froning and Neelakantam (1971) reported that the meat batter made from pre-rigor muscle exhibited higher emulsifying capacity and emulsion stability than those of post-rigor muscle. A higher cooking yield was observed from hot-cut broiler than the chill-cuts in broiler meat (Wyche and Goodwin, 1974). Due to the rapid muscle retrieval, hot-boning process has been known for many advantages such as energy saving, high processing yield, high throughput, reduced chilling time, and chilling space (McPhail, 1995; Lyon and Hamm, 1986).

In poultry, however, hot-boned processing has to be completed in < 0.5 h post mortem because rigor in poultry muscle starts early while rigor in pork and beef develops in 0.25 – 3 h and 6 – 12 h, respectively (Aberle et al., 2001). Furthermore, HB presents difficulties in synchronizing speed between slaughtering and boning lines, controlling hygiene, and making initial investment with worker retraining (Troy, 2006; Pisula and Tyburcy, 1996).

Cold-batter mincing is an emerging technology, which improves protein functionality and gel forming ability during mincing the meat batter for a long period of time at sub-zero temperatures. As a result, the hot-boned/crust-frozen muscles have the great potential for cold-batter mincing rather than the simultaneous mincing of hot-boned muscles (synchronizing issue, PSE-like softening issue if delayed for chilling) or freezing of hot-boned muscle (thaw-rigor issue after thawing).

In 1965, Bard (1965) reported interesting results in protein extraction as follow: 1) the extraction of salt-soluble proteins from post-rigor meat increased proportionally as the extraction time was extended up to 15 h, 2) protein extraction increased dramatically in the range of -5 to 2^{o}C compared to the temperatures higher than 2^{o}C, and 3) muscle protein extraction from pre-rigor meat was greater in 15 min mincing than that from post-rigor muscle minced for 15 h. When pre-rigor meats were salted and ground with carbon dioxide, patties from the pre-rigor meat had higher pH, lower cooking loss, and firmer texture than those from post-rigor control (Sorheim et al., 2006).

Previously cold-batter mincing of hot-boned/¼ sectioned/crust-freezing air chilled turkey fillets minced for 7 min generated higher stress and strain values in cooked gels than those of chill-boned control and hot-boned/no-chilled muscles. Therefore, the purpose of this research was to evaluate the potential for protein functionality improvement and sodium reduction capability by extending cold-batter mincing time for HB-¼CFAC fillets up to 24 min.

4.3 Materials and Methods

4.3.1 Turkey slaughter and dressing, carcass chilling, and sample preparation

Four batches of twelve live Nicolas tom turkeys (16 weeks-old, ~18 kg in live weight) each, were obtained locally in four different occasions between July and December of 2012. Four replications were completed at the end of this study, and a total of forty-eight turkeys (twelve turkeys per batch) were used.

After birds were withdrawn from feed for 12 h and cooped in plastic cages, the birds were transported to the Michigan State University meat and poultry processing laboratory. On the morning of the arrival, the birds were electrically stunned for 6 s (80 mA, 60 Hz, 110 V), and bled for 90 s by severing both carotid artery and jugular vein on one side of the neck. The turkeys were then scalded (59ºC, 120 s), mechanically defeathered (25 s), and manually eviscerated. After washing, carcasses were weighed, and their internal temperatures were recorded from the center of the turkey breast using a digital thermometer/logger (model 800024, Sper Scientific Ltd., Scottsdale, AZ).

In each replication three out of the twelve carcasses were randomly assigned to one the following treatments (Figure 4.3.1.):

1) Water Immersion Chilling, cold-boned, and minced traditionally with 2% table salt **(CB-T 2%)**
2) Water Immersion Chilling, cold-boned, and minced traditionally with 1% table salt **(CB-T 1%)**
3) Hot-boned, crust-freeze-air chilled in quarter portions, and minced at sub-zero temperatures with 2% salt **(HB-¼CFAC-2%)**
4) Hot-boned, crust-freeze-air chilled in quarter portions, and minced at sub-zero temperatures with 1% salt **(HB-¼CFAC-1%)**

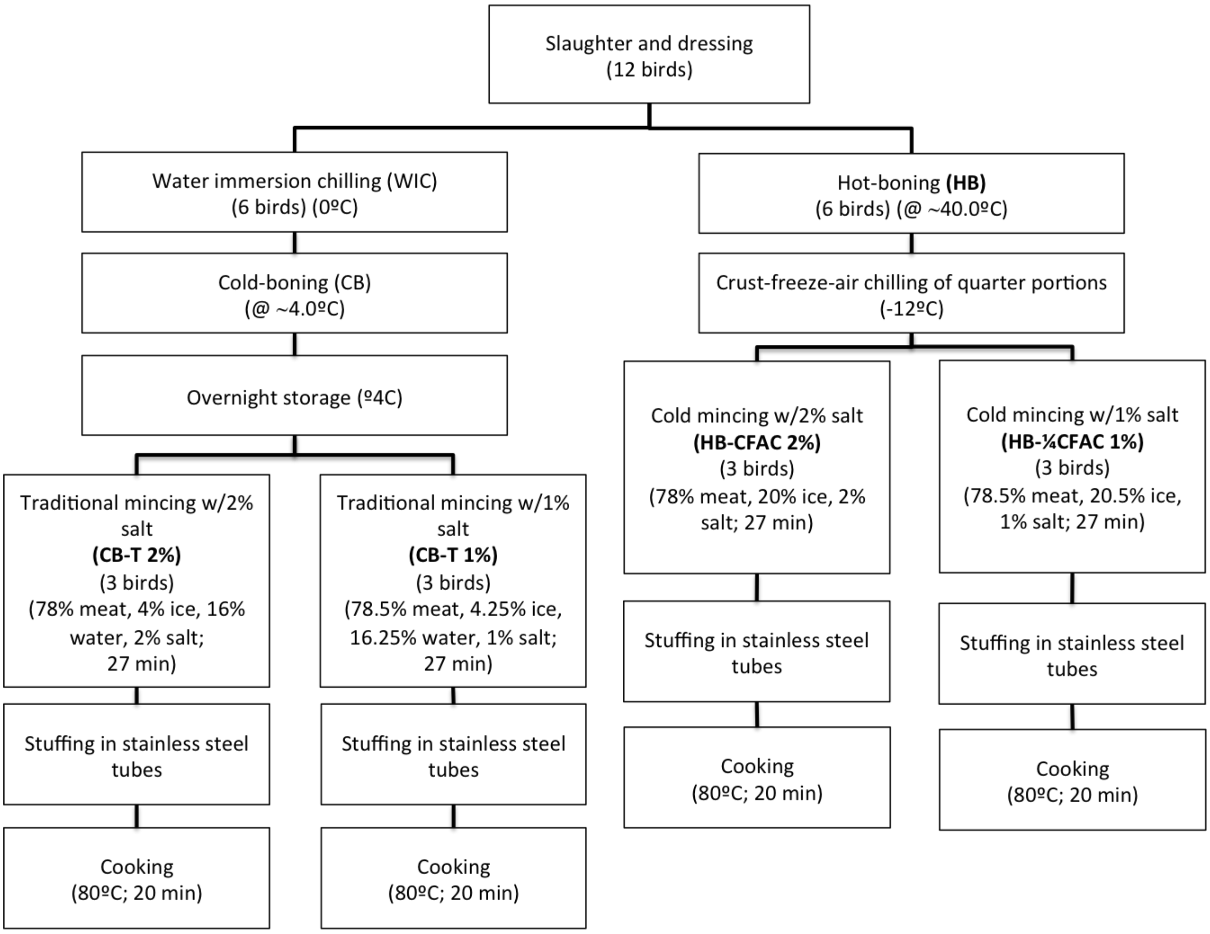


Figure 4.3.1. Process flow for study 2

All six WIC turkeys were chilled in two plastic tanks (3 birds per tank), each containing a mix of water and ice (~40 L @approximately 0.5ºC) (Figure 3.3.3 A, A') with mechanical agitation (0400–025GV1S portable agitator, Grovhac Inc., Brookfield, WI). The temperature of one representative carcass was measured every five minutes and recorded. The carcasses were taken out of the chilling tank after reaching 4ºC. The carcasses were then cold-boned **(CB)**, and samples (1 cm thickness) from the cranial, medial, and caudal portions (Figure 3.3.2) of the right breasts (one sample per carcass) were immediately taken and tagged, placed in temperature resistant plastic bags, frozen in liquid nitrogen, and stored in a freezing room (-20.0ºC) for further testing. The left breasts were stored in gallon-size Ziploc bags in a chilling room (4.0ºC) for overnight storage.

The remaining six birds were hot-boned **(HB)**, and samples from the right breasts were taken and stored immediately after hot-boning in the same way as mentioned above. HB-NC and HB-CO_2 breasts were processed immediately as described in the *Breast mincing and gel preparation* section of this chapter. The left HB-CFAC breasts were manually sliced into four portions of similar size (Figure 3.3.3), and placed in an air freezing room (~1 m/s, @12^{o}C) for CFAC (Figure 3.3.4 C, C').

The temperature of one representative breast was taken every 5 min for each CFAC treatment. The breasts were taken out of the freezing room after reaching an internal temperature of 4ºC. Samples from the frozen meat were then taken and stored in the same fashion as for WIC treatment. The remaining frozen meat was minced directly after chilling.

4.3.2 Breast mincing

All four treatments were minced in a food cutter (256 rpm, Models 84181, Hobart, Troy, OH) in the meat processing lab at Michigan State University. Each batch (~25 Kg) was mixed for 27 min using the following formulations:

CB-T 2%: 78% chilled-boned meat, 4% water (25ºC), 16% ice (0ºC), and 2% table salt

CB-T 1%: 78.5% chilled-boned meat, 4.25% water (25ºC), 16.25% ice (0ºC), and 1% table salt

HB-¼CFAC 2%: 78% crust-freeze-air chilled breasts in quarter portions, 20% ice (0ºC), and 2% table salt.

HB-¼CFAC 1%: 78.5% crust-freeze-air chilled breasts in quarter portions, 20.5% ice (0ºC), and 1% table salt.

Two separate sets of 50 g samples were taken from each batter every 3 min, starting at min 6, until min 27, placed in temperature resistant plastic bags, and labeled; one of the two sets was stored in an ice bed, and immediately taken to the testing lab for protein solubility determination, while the second set was immersed in liquid nitrogen, and placed in a freezing room (-20ºC) until tested for pH. Each batter was placed in a gallon size Ziploc bag, and stored overnight in a chilling room (4ºC) before gel preparation.

4.3.3 Gel preparation

After mincing, batters were cooked into gels using the method of Jeong et al. (2011). Each treatment batter was stuffed into pre-weighed stainless steel cylindrical tubes, and put into a water bath (model 25, Precision Scientific Co., Chicago, IL) at 80°C for 20 min. After cooking, the tubes were immediately placed in an ice bed to reach room temperature, before being tested for cooking yield and texture.

4.3.4 Sample Testing

The samples for pH determination were measured from the previously frozen medial portions of the right fillets and from frozen batters. The sample preparation followed the procedure used by Sams and Jancky (1986), and done in duplicates for each sample. After storage (-20ºC) the samples were individually placed in new temperature-resistant plastic bags, immersed in liquid nitrogen for further freezing, double wrapped in aluminum foil and paper towel, and pulverized using a hammer. 2.5 g of each powdered sample were homogenized in 25 mL of homogenizing solution (0.005M Iodacetate) for 30 sec. using a benchtop homogenizer. The homogenized samples were let to reach room temperature before determining the pH, which was measured with a pH electrode (model 13-620-631, Fisher Scientific Inc., Houston, TX) attached to a pH meter (Accumet AR15, Fisher Scientific Inc., Pittsburgh, PA).

The ratio of inosine-monophosphate:adenosine-triphosphate (R-value) was assessed as an indicator of adenosine triphosphate (ATP) depletion in the muscle, using the method of Thompson et al. (1987). Previously frozen medial portions of the right fillets were used to determine R-value. After storage (-20ºC) the samples were individually placed in temperature-resistant plastic bags, immersed in liquid nitrogen, double wrapped in aluminum foil and paper towel, and pulverized using a hammer. 3.0 g of powdered sample were placed into a plastic beaker with 20 ml of 1M perchloric acid, and homogenized for 1 min on 60% power using a benchtop homogenizer. The homogenized samples were then filtered through filter paper, and 0.1 ml of the filtrate was transferred to a disposable glass tube, where 4.0 ml of 0.1M phosphate buffer were added. The absorbance of this solution was read at 250 nm (IMP) and 260 nm (ATP), as indicators of Inosine and Adenosine respectively. The following equation was used to get the R-value:

$$\frac{A250}{A260} = R\text{-}value$$

To determine the degree of solubilized protein in each treatment, the batter samples were tested immediately after mincing following the method and formula of Xiong and Brekke (1989). To prepare the salt-soluble protein sample, 1.0 g of fresh batter was mixed with 40 ml of extraction buffer (DDW-double distilled water), stomached for 1 min, placed in centrifuge tubes (1 ml), and centrifuged for 5 min (12 g, 40ºC). To determine total protein, 2g of turkey batter sample (from min 3 sample) were mixed with 15 mL of urea buffer (8M urea in 20mM Tris-HCL, pH 5.7-5.9), stirred magnetically overnight, and centrifuged for 5 min (12 g, 40ºC). Protein concentration of all salt-soluble samples (eight samples per treatment, one for each 3 min of mincing), and total protein samples (one per treatment from min 3) was determined using Thermo Scientific™ Pierce™ BCA™ Protein Assay. Protein solubility was calculated using the following formula:

$$\frac{[Solubilzed\ Sample\ Protein]}{[Total\ Protein]} x\ 100 = Protein\ Solubility$$

The cooking yield (percentage of the initial weight of the meat batter retained after cooking) was determined by individually weighing the ten tubes used for each treatment, prior to (empty tube and two caps), and after stuffing (stuffed tube and two caps). After cooking and cooling, the purged water was drained off the tubes, and each cooked gel and its cooking tube were dry with paper towels, and weighed together. All weights were recorded and the final cooking yield was determined with the following formula:

$$\frac{Wt_{ad} - Wt_{bs}}{Wt_{st} - Wt_{bs}} * 100 = \%\ Cooking\ yield$$

Wt_{bs}= Weight of tube before stuffing

Wt_{st}= Weight of stuffed tube

Wt_{ap}= Weight of dried drained tube with cooked gel

To determine shear stress and shear strain, as indicators of hardness and elasticity respectively, the cooled cooked gels were cut perpendicularly in 3.0 cm length cylinders after reaching room temperature (25ºC). Styrene disks were glued to the upper and lower bases of the 3.0 cm cylinders using Loctite® Super Glue Liquid. The samples were then milled into a dumbbell shape (10 mm in diameter at the midsection) by using a shaping machine (KCI-24A2, Bodine Electric Co., Raleigh, NC). Each specimen was placed on a viscometer (DV-III Ultra, Brookfield Engineering Laboratories Inc., Middleboro, MA) and twisted at 2.5 rpm. Ten samples were evaluated for each treatment for 3 separate replications. At the breaking point, both shear stress and shear strain were calculated with the recorded torque and elapsed time using the following equations (Hamann, 1983):

$$\frac{Tq * 1582}{100} = Stress$$

$$[(t * 0.2618) - (Tq * 0.0148)] * 0.5724 = Strain$$

t= Time at fracture

Tq= Torque (%)

For SEM evaluation, both meat batters and cooked gels (3 mm × 3 mm × 3 mm cube) were fixed at 4^{o}C for 2 h in 4% glutaraldehyde buffered with 0.1 M sodium phosphate at pH 7.4. Following a brief rinse in the buffer, samples were post-fixed in 1% osmium tetroxide buffered with 0.1M sodium phosphate for a minimum of 4 h. Samples were then briefly rinsed in 0.1 M phosphate buffer and dehydrated by exchanging with graded ethanol series (25, 50, 75, and 95%) for 1 h at each gradation with additional three 1 h changes in 100% ethanol. The resulting samples were then mounted on aluminum stubs using carbon suspension cement (SPI Supplies, West Chester, PA) and coated with osmium (~10 nm thickness) in a NEOC-AT osmium coater (Meiwafosis Co., Ltd., Osaka, Japan). Samples on the aluminum stubs were examined in a JEOL JSM-7500F (cold field emission electron emitter) scanning electron microscope (JEOL Ltd., Tokyo, Japan).

4.3.5 Statistical Analysis

All experiments, with the exception of SEM, which was only done once, were replicated 3 times. Data were evaluated using PASW 18 statistic program (2009) by one-way ANOVA, and a post-hoc analysis was performed with Duncan's multiple range test to evaluate difference among treatments.

4.4 Results and discussion

The initial temperature (41.3°C) of the eviscerated turkey carcasses decreased to 4°C, with an average chilling time of 5.5 h for water immersion chill (WIC), and of 1.0 h for the fillets in crust-freeze-air room (~1 m/s, @-12°C) after hot-boning/¼sectioning/crust-freezing air-chill (**HB-¼CFAC)**. These results were similarly noticed in the previous chapter of this thesis. Before chilling, there were no significant differences between two groups of fillets (chill boning and hot boning) for pH (6.04 – 6.14) and R-values (0.98 – 1.01) (Table 4.4.1). After chilling, higher pH (5.94) and lower R-value (1.19) ($P < 0.05$) were observed in HB-¼CFAC fillets than those (pH 5.72, R-value 1.32) of chill boned (**CB**) fillets (Table 4.4.1), indicating that less glucose and ATP have been hydrolyzed in the HB-¼CFAC fillets than those in CB fillets, primarily due to a shorter PM time (15 min) than that (345 min) of CB fillets. Alvarado and Sams (2002) also observed that turkey breasts at 15 min postmortem had higher pH (6.16) and lower R-value (1.02) than those (pH 5.91, R-value 1.3) of 24 h.

Table 4.4.1. pH and R-value (±SEM)[1] of turkey breasts before and after being chill-boned (CB) or hot-boned/¼ sectioned/crust-freezing air chilled (HB-¼CFAC)

Parameter/Chilling	CB	HB-¼CFAC
pH before chill	6.04 ± 0.18^{a}	6.14 ± 0.21^{a}
pH after chill	5.73 ± 0.09^{b}	5.94 ± 0.10^{a}
R-value before chill	1.01 ± 0.09^{a}	0.98 ± 0.08^{a}
R-value after chill	1.32 ± 0.05^{a}	1.19 ± 0.13^{b}

[a,b]Means within a row with the same superscripts are not significantly different ($P < 0.05$).
[1]The number of observations in each chilling for each part, n = 16.

After chilling, breast fillets were minced with 1 or 2% salt for a batter preparation. For a cold-batter mincing, HB-¼CFAC fillets (surface temperature at -1.5 to -3.5°C) were minced with 2% salt/20% ice or 1% salt/21% ice, while CB fillets (surface temperature at ~ 0.5°C) were traditionally minced with 2% salt/4% ice/16% water or 1% salt/4% ice/17% water. During the first 6 min of mincing, temperatures of traditional-minced batter sharply increased to 17 – 18°C, while those of cold-mincing batter remained at -1°C (Figure 4.4.1). After 6 min, the temperature of cold-minced batter continuously increased and had no significant difference ($P > 0.05$) from the traditionally-minced batters at 15 min for 2% salt and 24 min for 1% salt (Figure 4.4.1). Regarding the traditional chopping time and batter temperature, Deng et al. (1981) reported that temperature increased to 16°C at 5 min mincing and 33°C at 20 – 25 min, which supports these results of traditional batters.

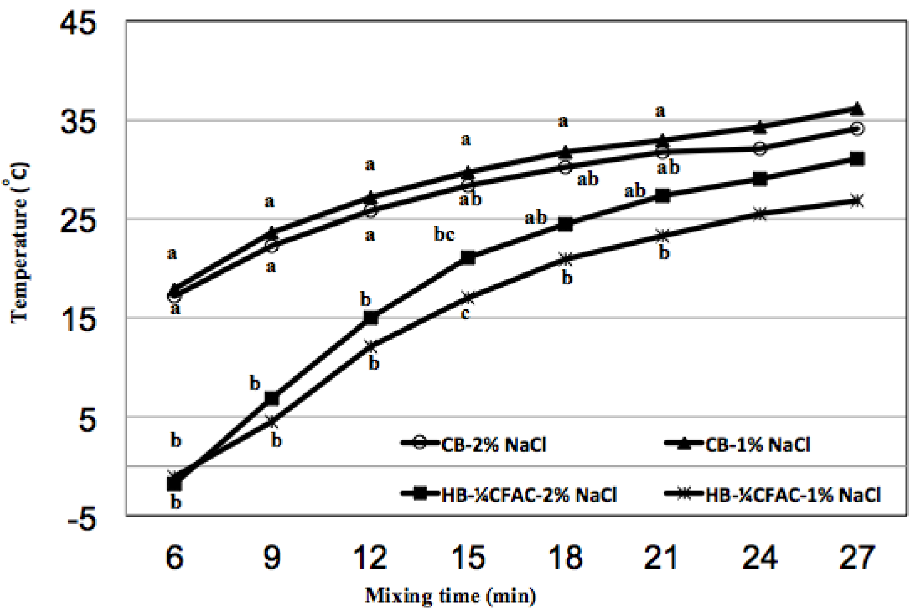


Figure 4.4.1. Temperature changes of meat batters during 27 min mincing of turkey fillets that were chill-boned (CB) or hot-boned/¼sectioned/crust-freeze-air-chilled (HB-¼ CFAC). Means (n = 8) with no common letters within the same mincing time differ significantly ($P < 0.05$)

At 6 min mincing, the pH (5.97) of 2% salt HB-¼CFAC batter was higher ($P < 0.05$) than that (pH 5.82) of 1% salt CB batter, with intermediate values (pH 5.83 – 5.90) for the 1% salt HB-¼CFAC and 2% CB. After 6 min, the pH of 1 and 2% salt HB-¼CFAC batters continuously decreased to 5.75 and 5.55, respectively at the end of mincing, resulting two lowest pH values (Figure 4.4.2). Unlike the HB-¼CFAC, the pH of CB batters remained constant in the range of 5.8 ± 0.2 throughout the mincing period, regardless of salt content. As a result, the CB batter pH was the same as the 2% salt HB-¼CFAC batter and significantly higher ($P < 0.05$) than the 1% salt HB-¼CFAC batter after 15 min mincing. It has been known that the pH of pre-rigor meat rapidly drops when the pre-rigor meat are ground or turned into batter.

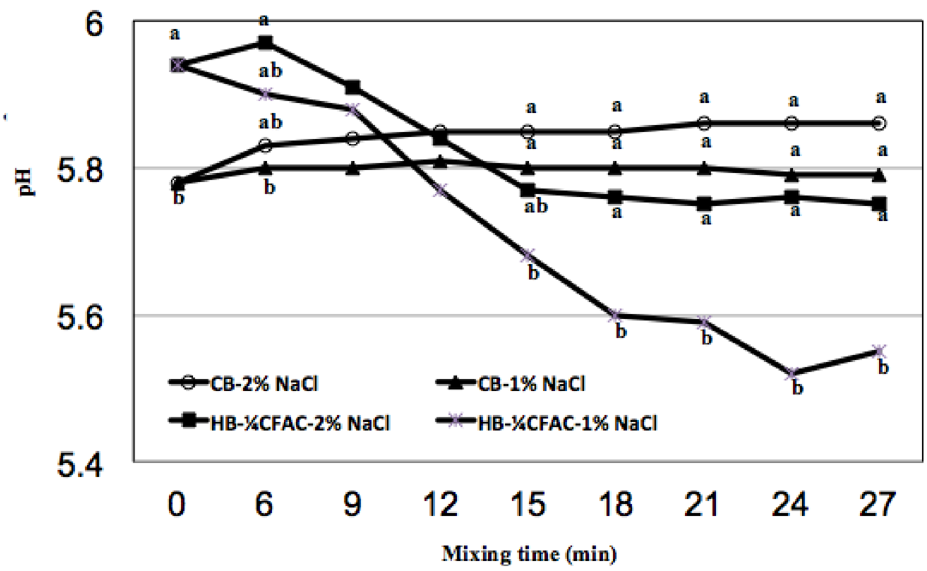


Figure 4.4.2. pH changes of meat batters during 27 min mincing of turkey fillets that were chill-boned (CB) or hot-boned/¼sectioned/crust-freeze-air-chilled (HB-¼ CFAC). Means (n = 8) with no common letters within the same mincing time differ significantly ($P < 0.05$)

Newbold and Scopes (1971) reported that the pH of minced pre-rigor beef decreased from 6.7 to 5.4 – 5.5 during 400 min storage, while the intake muscle pH remained in 6.3 – 6.4. Bernthal et al. (1989) also observed that beef muscle pH was significantly reduced when pre-rigor muscles were ground and stored, while high ultimate pH values were observed at high NaCl concentrations. Hamm (1977) reported that grinding of pre-rigor beef muscle with 2 – 4% sodium chloride inhibited glycolysis in several hours postmortem, due to the denaturation of glycolytic enzymes in low pH (< 6) and high ionic strength. In follow-up research, salt was recommended to add to pre-rigor blend for 1.5% (Farouk and Swan, 1997), 1.8% (Hamm, 1982), or 2.0% (Bernthal et al., 1989) for high muscle pH and high protein functionality.

When the batters were taken during mincing and stored at 4^{o}C overnight, the overall pattern of the overnight batter pH was similar those of fresh batter pH except the 1% salt HB batter, resulted in additional pH reduction by 0.1 – 0.2 units (Figure 4.4.3). It appears that the grinding time of pre-rigor muscle for batter generation might more affect the batter pH than the storage of the batter for overnight. These outcomes are consistent with the previous findings that the ultimate pH of 1.5% salt HB beef mince was always higher than that of unsalted controls (Farouk and Swan, 1997), indicating that the mincing of HB muscle at high salt maintains a high pH compared to the mincing of HB muscle at low salt. Torres et al. (1988) also indicated that ground HB beef containing 2.0% salt had lower pH (0.7 – 0.9 units) than those of 4.0% salt. Regardless of pH values at the time of freezing, mincing of unsalted muscles reached ultimate pH values to 5.6 – 5.75, indicating that the glycolysis continued during thawing at 4°C for 48 h (Farouk and Swan, 1997). In this study, glycolysis was presumed to occur in the 1% salt more than the 2% salt HB-¼CFAC batter during overnight storage.

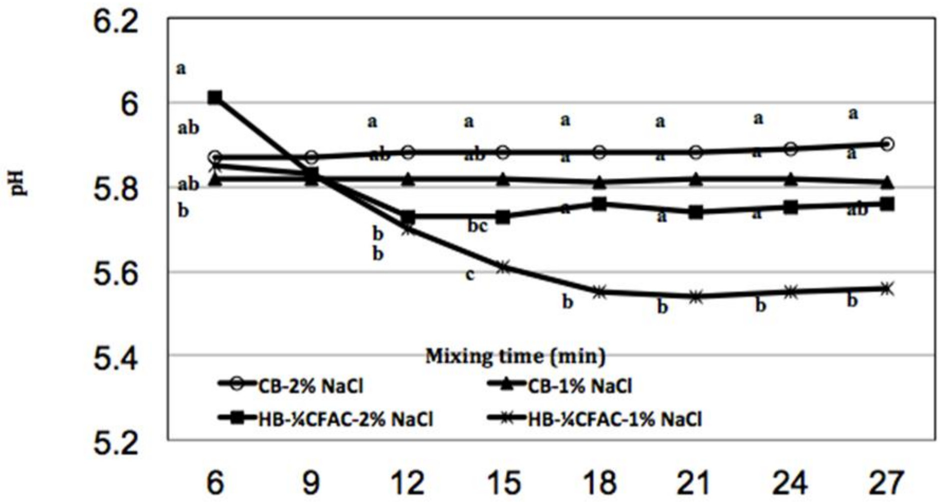


Figure 4.4.3. pH changes of overnight-stored (4°C) meat batters that were made with turkey fillets chill-boned (CB) or hot-boned/¼sectioned/crust-freeze-air-chilled (HB-¼ CFAC). Means (n = 8) with no common letters within the same mincing time differ significantly ($P < 0.05$)

Studies have shown that salt-soluble proteins in pre-rigor muscle are extracted more than post-rigor muscle (Saffle and Galbreath, 1964; Bernthal et al., 1989; Claus and Sorheim, 2006). The solubilized proteins in HB-¼CFAC batters ranged from 44% to 54% during the entire mincing, except the 6 – 12 min batters in 1% salt, while those of CB controls did not exceed more than 37% (Figure 5). Similarly, Bernthal et al. (1989) reported that the extractable protein values were 50 and 49% in pre-rigor homogenates in 1 and 2% salt, respectively, while the extractable protein value of post-rigor homogenate was 29%, regard ess of the salt content.

Shear stress (a measure of gel strength), representing sensory hardness, at breaking point of gel in Hamann Torsion Gelometer is primarily affected by protein content water content of gels, whereas shear strain (a measure of gel deformability, representing sensory cohesiveness) at failure of gel is affected by protein quality (Hamann and Lanier, 1987).

During mincing, failure stress values of 1 and 2% salt HB-¼CFAC gels sharply increased to the highest value of 48 kPa at 9 min and 39 kPa at 15 min, respectively, after both values gradually decreased to 32 – 36 kPa. Similarly, the stress values from CB gels increased to 26 kPa for 2% salt at 9 min and 23 kPa for 1% salt at 12 min, which were significantly lower ($P < 0.05$) than those of HB-¼CFAC (Figure 4.4.4).

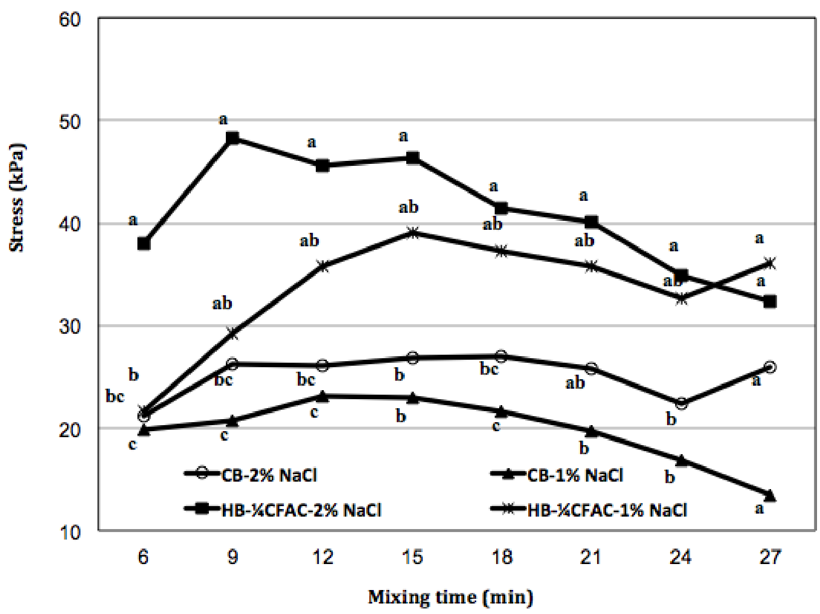


Figure 4.4.4. Stress value (kPa) of meat batters during 27 min mincing of turkey fillets that were chill-boned (CB) or hot-boned/¼sectioned/crust-freeze-air-chilled (HB-¼ CFAC). Means (n = 8) with no common letters within the same mincing time differ significantly ($P < 0.05$)

Unlike the stress values, no significant differences were found in strain values with the range difference of 1.0 ± 0.2, regardless of boning type and sodium content (Figure 4.4.5). The higher stress values in HB-¼CFAC can be explained by more protein extracted during the cold mincing (Figure 4.4.6), and the similar strain values can be explained potentially by the protein integrity, which affected during the preparation of fillets and gels.

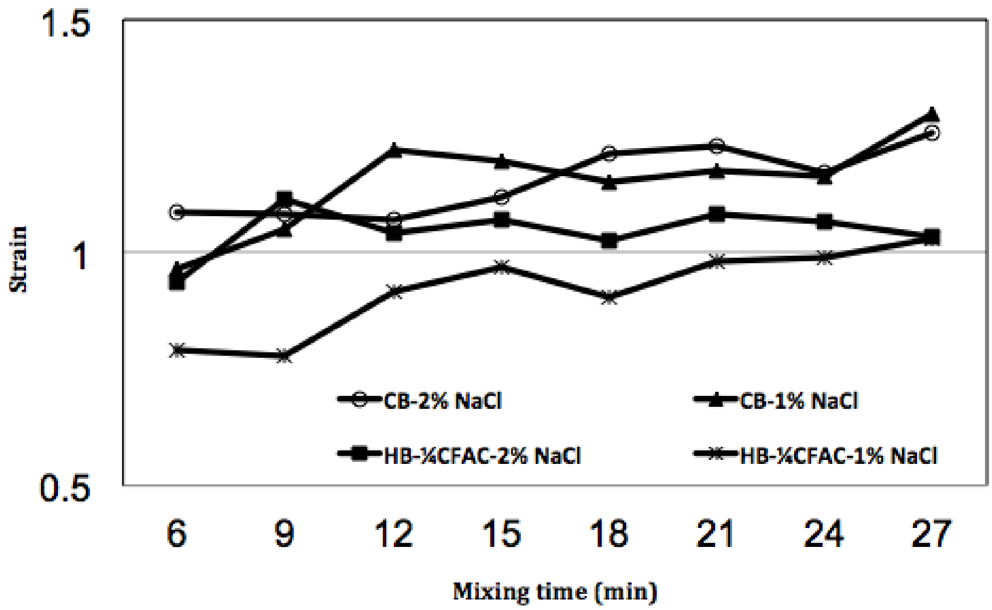


Figure 4.4.5. Strain value of meat batters during 27 min mincing of turkey fillets that were chill-boned (CB) or hot-boned/¼sectioned/crust-freeze-air-chilled (HB-¼ CFAC). Means (n = 8) with no common letters within the same mincing time differ significantly ($P < 0.05$)

Different from these results, Dibble (1993) reported that beef sausages made from pre-rigor salted beef has a lower stress value (29 kPa) than that (33 kPa) of post-rigor with a similar strain value (1.69 – 1.65) (Hamann and MacDonald, 1992). The lower stress value can be potentially explained by a higher water holding capacity, lowering the protein content, in the pre-rigor gel prepared from a traditional mincing but the HB-¼CFAC protein in this study is extracted significantly more during the cold-batter mincing than the CB protein in traditional mincing (Figure 4.4.5), potentially resulting in less reduction of stress value. Farouk and Swan (1997) also reported similar stress (~ 28 kPa) and strain (~1.7) values when hot-boned beef muscle was used at pH 6.0. In the previous study, the similar cold mincing method was used for 7 min mincing and generated similar strain (51 kPa) and stress (1.61) values of turkey gel.

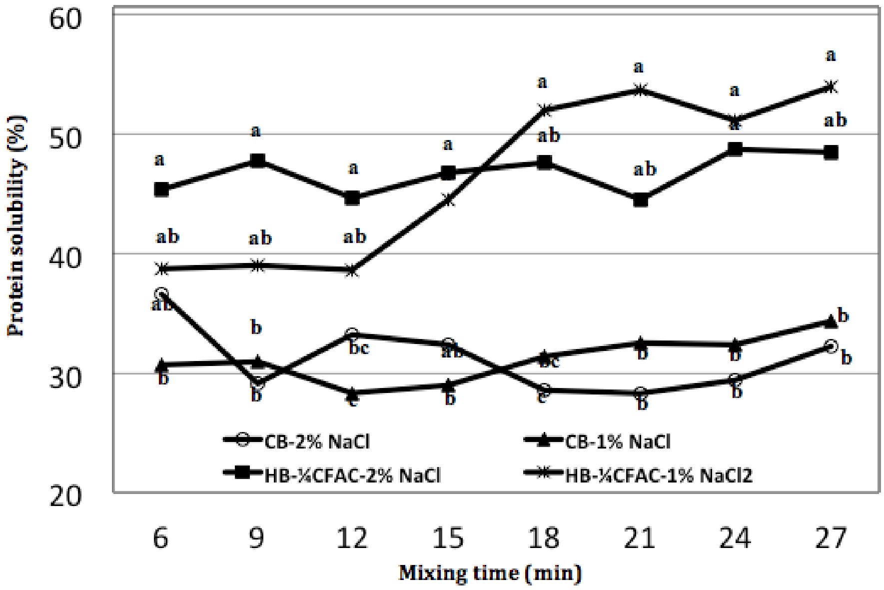


Figure 4.4.6. Protein solubility (%) of meat batters during 27 min mincing of turkey fillets that were chill-boned (CB) or hot-boned/¼sectioned/crust-freeze-air-chilled (HB-¼ CFAC). Means (n = 8) with no common letters within the same mincing time differ significantly ($P < 0.05$)

The functional property of heat-induced gels is closely related with three-dimensional gel-structure influenced by types of meats, muscles, amounts of connective tissues, pH, salt, and heating conditions (Clark and Lee-Tuffnell, 1986). In scanning electron micrographs, the batter properties of structural integrity, fat droplet entrapment, and matrix complex with connective tissues were detected more clearly in 2% salt HB-¼CFAC batter at 6, 12, and 24 min (Figure 7A, B, C) than those of 2% salt CB batter (Figure 4.4.7. A', B', C'). A similar pattern of results was observed in 1% salt HB-¼CFAC batter (Fig 4.4.8. A, B, C), whereas collapsed structure and fluffed appearance were seen in 1% salt CB batters at 12 and 24 min (Figure 8B', C'), respectively. These structural differences observed in SEM are closely related to the higher stress values seen in the HB-¼CFAC batters than the CB batters. Froning and Neelakantan (1971) stated that the photomicrographs of pre-rigor emulsions showed a thicker matrix around the fat globules, which might improve cohesive properties thereby high rubberiness. The fat particles in 2% salt HB-¼CFAC batters appeared to be sufficiently encapsulated with proteins at 6 min mincing (Figure 4.4.7 A), which became smaller in size as the chopping was continued (Figure 4.4.7 B, C), whereas the fat particles in 2% salt CB batters were small in size at 6 min mincing (Figure 4.4.7 A') and became almost undetectable at 12 and 24 min mincing (Figure 4.4.7 B', C').

Comparing cooked gels prepared from comminuted turkey batters at different pH values (4.5 – 7.5), Barbut (1997) reported that a dense structure with a considerable number of aggregates presented in the gels of pH 4.5 while more open structure with less aggregation were observed as the gel pH was raised from 5.5 to 7.5. In accordance with the Barbut's report, more open space and less aggregation were seen in 2% salt HB-¼CFAC gels (Figure 4.4.9 A, B, C) than those of 2% CB gels (Figure 4.4.9 A',B',C'). However, those structural properties were observed less clearly between 1% HB-¼CFAC and 1% CB gels (Figure 4.4.9), presumably due to a rapid pH reduction (to pH 5.56) of 1% HB-¼CFAC batter and continuous low pH (5.8) of 1% CB batter during mincing (Figure 4.4.3). Hamm (1977) reported that high values of adenosine triphosphate (ATP), tissue pH and ionic strength in pre-rigor meat contributed to a strong repulsion between adjacent protein molecules that leads to an expanded structure for more fat and water binding after heat coagulation.

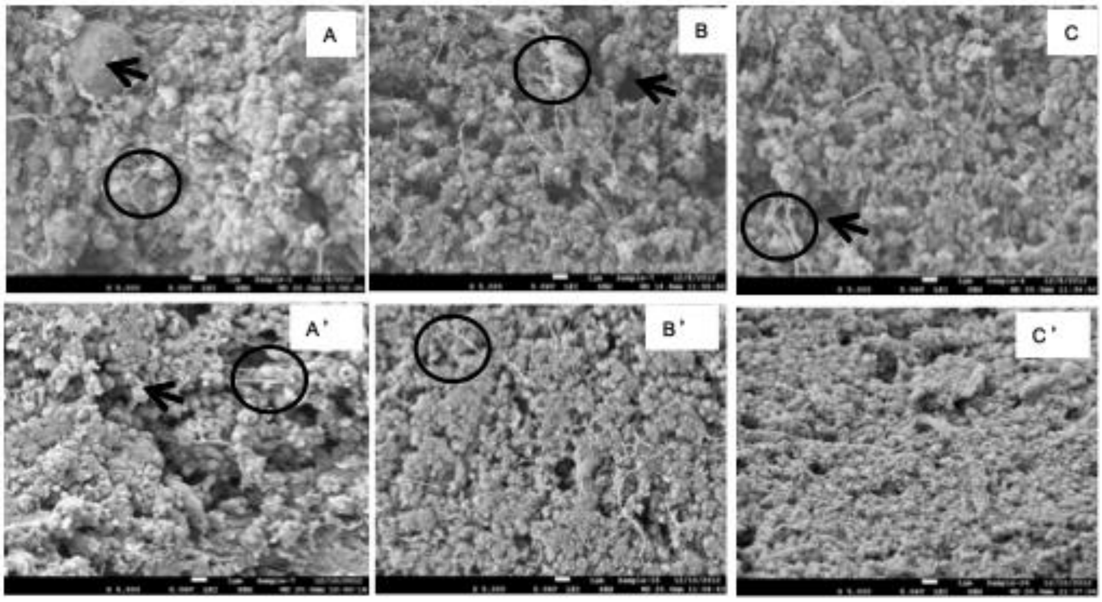


Figure 4.4.7 Scanning electron micrography (SEM) images of meat batters (2% salt) at 6, 12, 24 min mincing. Arrow: emulsified fat globule, Circle: connective tissue, bar=1µm. A: Meat batter of HB¼CFAC minced- 6 min, A': Meat batter of CB- 6 min, B: Meat batter of HB¼CFAC minced-12 min, B': Meat batter of CB minced-12 min, C: Meat batter of HB¼C FAC minced-24 min, C': Meat batter of CB minced-24 min

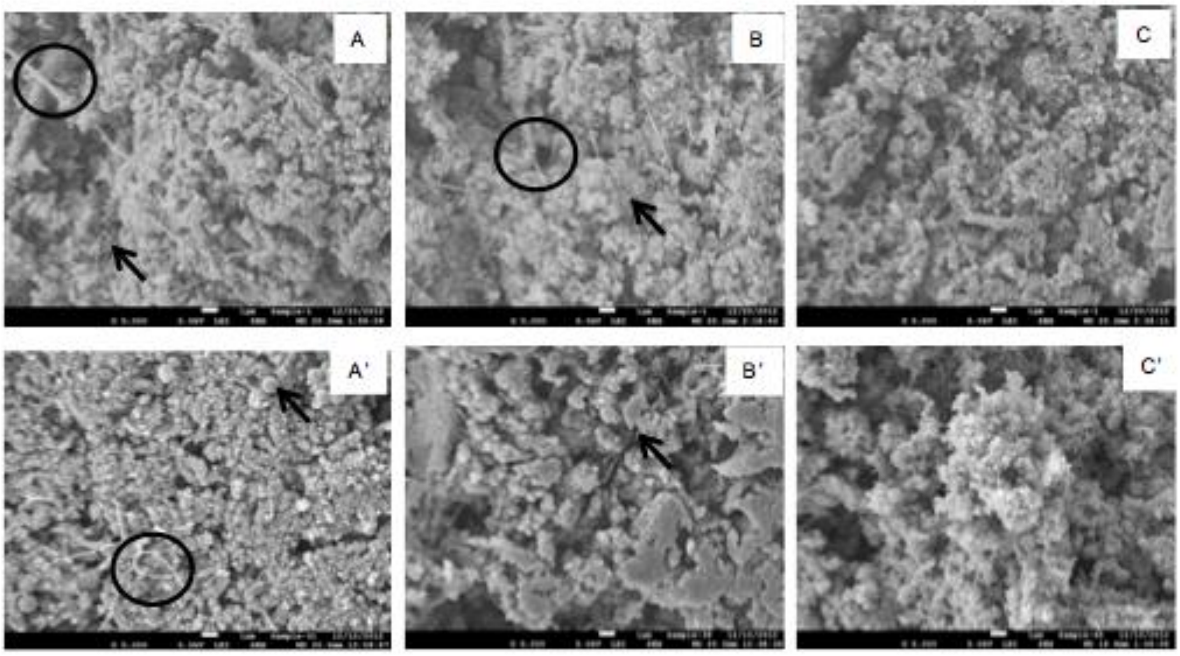


Figure 4.4.8 Scanning electron micrography (SEM) images of meat batters (1% salt) at 6, 12,24 min mincing. Arrow–emulsified fat globule, circle– connective tissue, bar = 1 μm. A: Meat batter of HB¼CFAC minced-6 min, A': Meat batter of CB minced-6 min, B: Meat batter of HB¼CFAC minced -12 min, B':Meat batter of CB minced -12 min, C: Meat batter of HB¼CFAC minced-24 min, C'.Meat batter of CB fillet minced -24 min

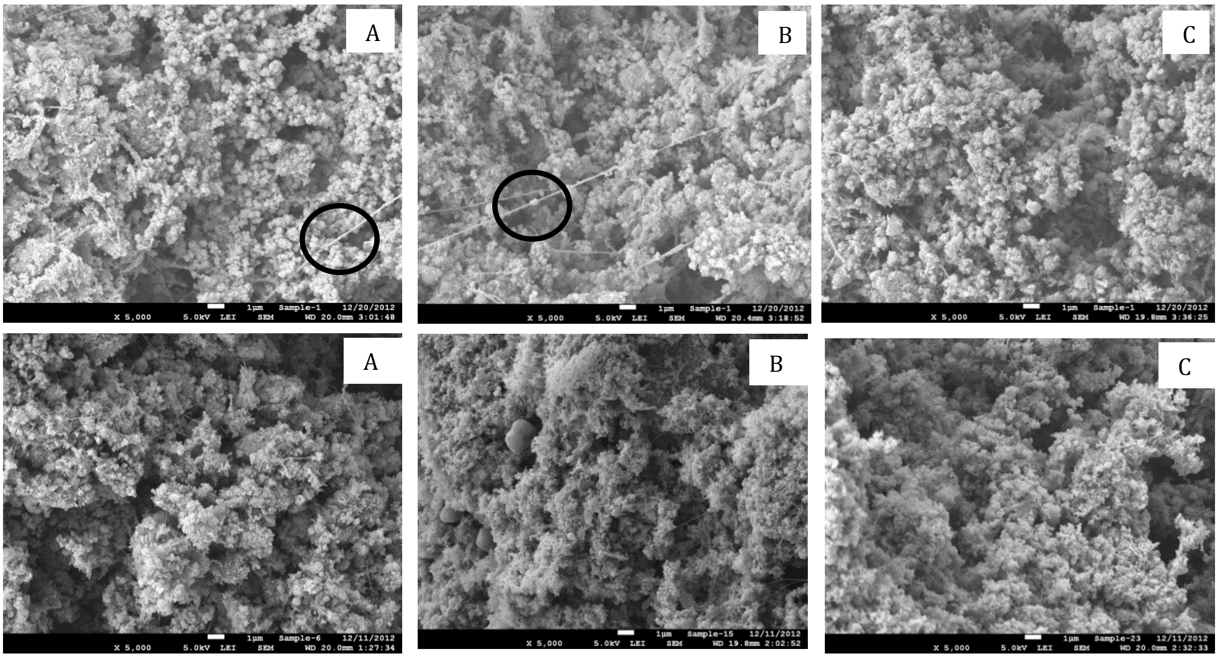


Figure 4.4.9. Scanning electron micrography (SEM) images of gels (2% salt) cooked after 6 min, 12, 24 min mincing. Circle– connective tissue, bar = 1 µm.
A: Meat gel of HB¼CFAC minced -6 min, A’: Meat gel of CB minced -6 min, B: Meat gel HB¼CFAC minced-12 min, B’: Meat gel of CB minced-12 min, C: Meat gel of HB¼CFAC minced -24 min, C’: Meat gel of CB fillet minced 24 min

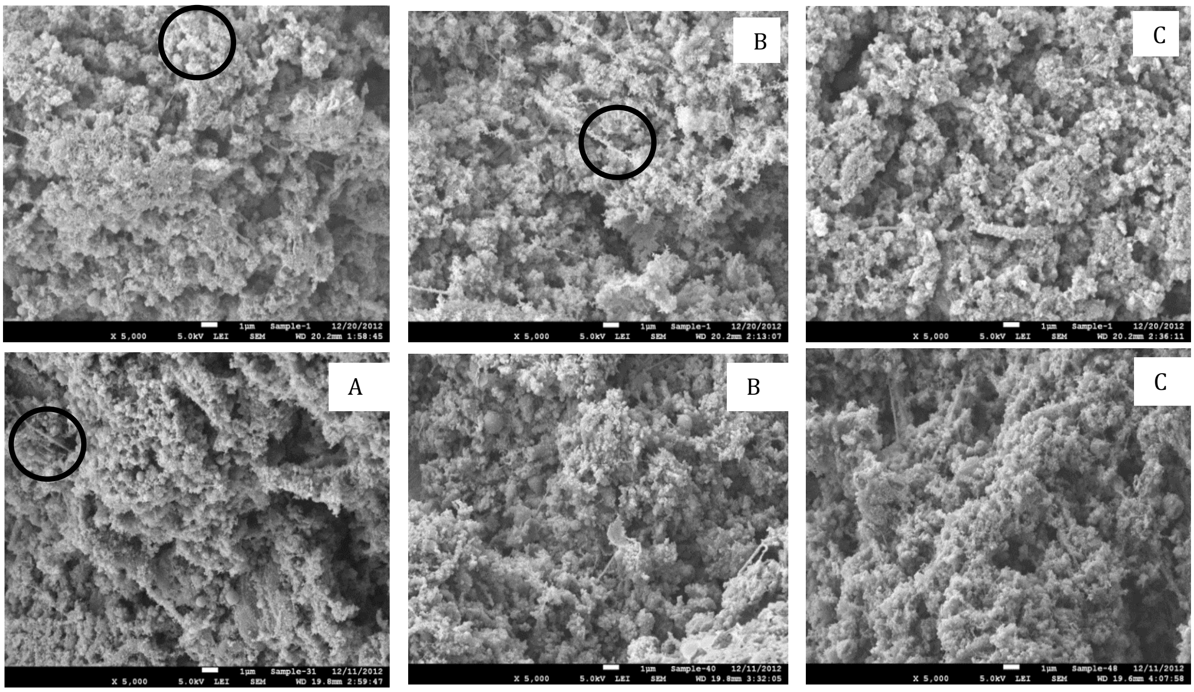


Figure 4.4.10. Scanning electron micrography (SEM) images of gels (1% salt) after 6, 12, 24 min mincing. Circle– connective tissue, bar = 1 µm.
A: Meat gel of HB-¼ CFAC minced 6 min, A': Meat gel of CB minced 6 min, B: Meat gel of HB-¼ CFAC minced -12 min, B': Meat gel of CB minced- 12 min, C: Meat gel of HB-¼CFAC minced -24 min, C': Meat gel of CB minced- 24 min

4.5 Conclusions

Over the past 25 years the average salt intake has increased approximately 56% in America, which has been related to an increase of negative health effects. However salt is a fundamental component of processed meat foods, and its reduction impacts the quality and processability of these products. The use of HB, to obtain pre-rigor meat, and CFC for rapid chilling, retained raw meat quality with high pH values, which when followed by CM with 2% and 1% sodium yielded similar results for pH, protein solubility, and gel strength and elasticity, to traditional chill-boned products with 2% salt when minced for less than 12 minutes. Particularly the use of HB-¼CFAC fillets in 1% of salt resulted in the extraction of more or similar amounts of protein when compared to the cold-boned/traditionally-minced control fillets in 2% salt. After cooking, the stress and strain values of HB-¼CFAC gel containing 1% salt were same as those of chill-boned control containing 2% salt. Lastly, the HB-¼CFAC technique provides additional advantages such as rapid meat turn over and high quality meats for various other applications. The use of scanning electron microscopy adds to previous studies about the structure of meat batter and gels, providing a general and broad overview about what happens to the structure of the components at different conditions.

CHAPTER V: AREAS FOR FURTHER STUDY

5.1. Areas for further study

The following topics are recommended for future study:

- Methods for maintaining constant temperature during batter mincing.
- Microbiological tests throughout the process, and on final products.
- Sensory analysis of finished products.
- Scale up costs and energy usage analysis.

APPENDICES

APPENDIX A

GLOSSARY OF TERMS

Protein functionality: in food processing, refers to any property of the protein that affects the attributes of the final product, such as water and fat binding, emulsifying capacity, and solubility.

Mincing: in meat processing, is the reduction of the meat particle size through the mechanical action of blades (usually in a bowl chopper), also refer to as comminution.

Batter: in meat processing refers to the homogeneous product resulting from mincing, also refer to as meat emulsion.

Traditional mincing: in this thesis, refers to the mincing of meat under conditions similar to those used currently in the meat industry (i.e. T= 10ºC)

APPENDIX B

PRODUCTION FLOW FOR EMULSIFIED PRODUCTS

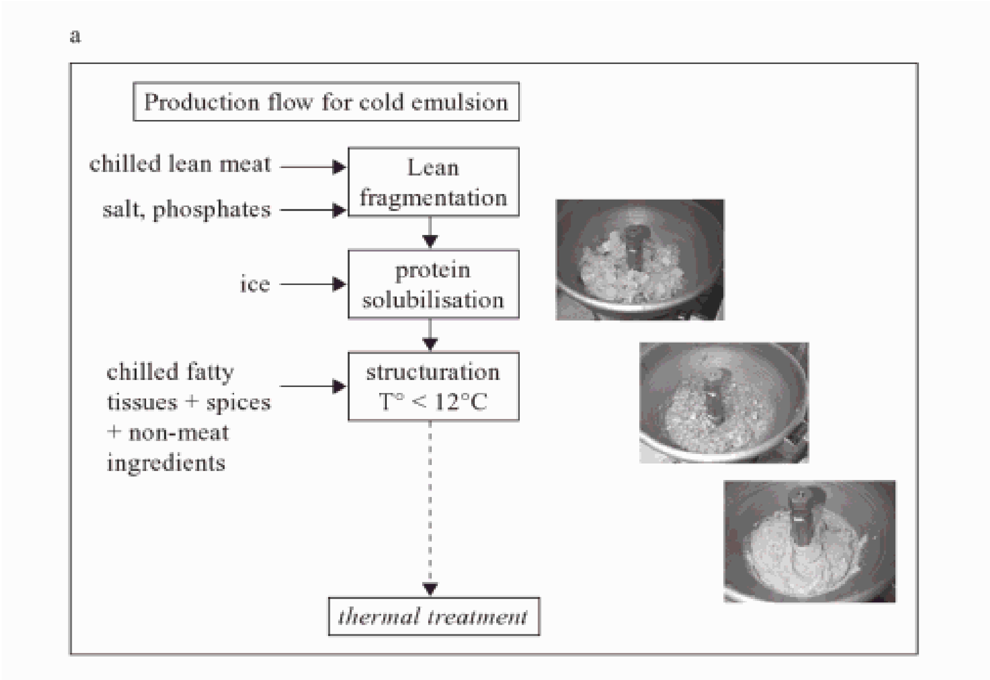


Figure B.1. Production flow for cold emulsions

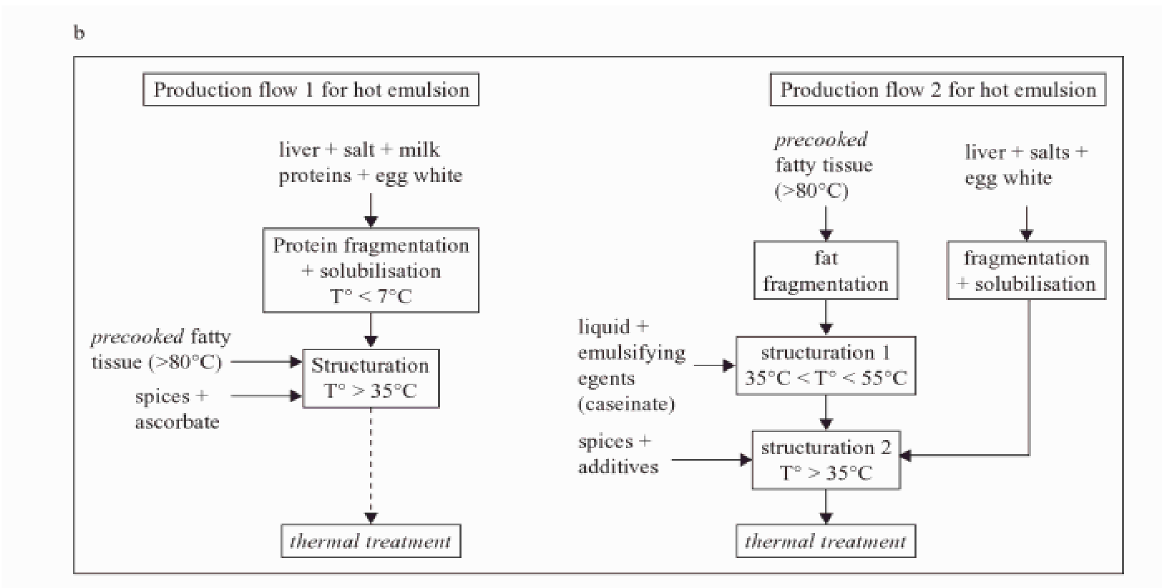


Figure B.2. Production flow for hot emulsions

APENDIX C

RAW DATA STUDY 1

Table C.1. Temperature monitoring - Replication 1

Temperature monitoring

Study 1 - Replication 1

Water Immersion Chilling

Time	Time interval	Post Rigor WC For carcass	Water Temp. ©
09:05	0	42.10	-0.20
09:10	5	42.10	-0.40
09:15	10	41.10	-1.00
09:20	15	40.40	-1.40
09:25	20	39.30	-1.70
09:30	25	38.00	-1.90
09:35	30	36.80	-1.90
09:40	35	35.90	-2.00
09:45	40	34.70	-1.90
09:50	45	33.40	-2.00
09:55	50	31.90	-2.00
10:00	55	30.90	-2.00
10:05	60	30.10	-2.00
10:10	65	28.50	-2.00
10:15	70	27.40	-2.00
10:20	75	26.40	-2.00
10:25	80	25.30	-2.00
10:30	85	24.10	-2.00
10:35	90	22.90	-2.00
10:40	95	22.00	-1.9
10:45	100	21.30	-2.00
10:50	105	20.40	-2.00
10:55	110	19.40	-2.00
11:00	115	18.20	-2.00
11:05	120	17.30	-2.00
	125		
11:15	130	16.10	-2.00
11:20	135	15.40	-1.90
11:25	140	14.70	-2.00
11:30	145	14.10	-1.80
11:35	150	13.40	-2.00
11:40	155	12.90	-1.90
11:45	160	12.10	-2.00
	165		
11:55	170	11.10	-1.90
12:00	175	10.40	-2.00
12:05	180	10.00	-2.00
12:10	185	9.60	-1.90
12:15	190	9.00	-2.00
12:20	195	8.50	-2.00
12:25	200	8.10	-2.00
12:30	205	7.80	-2.00
12:35	210	7.30	-2.00
12:40	215	7.00	-2.00
12:45	220	6.50	-2.00
12:50	225	6.10	-2.00
12:55	230	5.90	-2.00
13:00	235	5.60	-2.00
13:05	240	5.30	-2.00
13:10	245	5.00	-2.00
13:15	250	4.60	-2.10
13:20	255	4.40	-2.10
13:25	260	4.20	-2.00
13:30	265	3.80	-2.10

HB-CFAC

Time	Time interval	Pre Rigor IB For carcass	Chilling room Temp. ©	Chilling room Humidity (%)
13:00	0	41.10	-24.1	60.0%
13:05	5	41.10	-24.1	
13:10	10	37.10	-29.1	
13:15	15	33.60	-29.9	74.9%
13:20	20	31.40	-30.2	
13:25	25	27.90	-30.2	
13:30	30	24.40	-29.7	76.6%
13:35	35	21.70	-29.7	
	40			
13:45	45	17.30	-29.6	78.9%
13:50	50	15.30	-29.7	
13:55	55	13.30	-28	
14:00	60	11.30	-21.9	77.3%
14:05	65	9.50	-23.8	
14:10	70	7.90	-25.9	
14:15	75	6.80	-26.5	77.5%
14:20	80	5.60	-23.9	
14:25	85	4.40	-25.5	
14:30	90	3.60	-25.5	77.5%

HB- 1/4 CFAC

Time	Time interval	Pre Rigor IB 1/4 For carcass	Chilling room Temp. ©
13:50	0	36.4	-29.7
13:55	5	34.1	-28
14:00	10	29.1	-21.9
14:05	15	25.3	-23.8
14:10	20	21.2	-25.9
14:15	25	17	-26.5
14:20	30	13.1	-23.9
14:25	35	9.3	-25.5
14:30	40	7.2	-25.5
14:35	45	4.4	-25.5
14:40	50	2.5	-25.5

Table C.2. Batter and raw meat pH – Replication 1

pH

Study 1, replication 1

Sample Name		batter before overnight			batter after overnight			before chilling frozen raw meat				after chilling frozen raw meat			
		rep 1	rep 2	*avg*	rep 1	rep 2	*avg*	rep 1	rep 2	*avg*	avg	rep 1	rep 2	*avg*	avg
Treatment 1 Post Rigor WC	1							6.21	6.20	***6.21***		5.76	5.79	***5.78***	
	2	5.82	5.85	**5.84**	5.86	5.86	**5.86**	6.66	6.71	***6.69***	6.48	5.89	5.91	***5.90***	5.86
	3							6.54	6.57	***6.56***		5.88	5.92	***5.90***	
Treatment 2 Pre Rigor IG	1							6.38	6.65	***6.52***					
	2	6.06	6.07	**6.07**	6.04	6.04	**6.04**	6.46	6.51	***6.49***	6.51				
	3							6.51	6.52	***6.52***					
Treatment 3 Pre Rigor IG CO_2	1							6.57	6.63	***6.60***					
	2	6.36	6.32	**6.34**	6.05	6.04	**6.05**	6.61	6.69	***6.65***	6.52				
	3							6.31	6.29	***6.30***					
Treatment 4 Pre Rigor IB RC	1							6.57	6.58	***6.58***		6.00	6.02	***6.01***	
	2	6.040	6.040	**6.040**	5.940	5.930	**5.935**	6.18	6.22	***6.20***	6.40	6.25	6.31	***6.28***	6.16
	3							6.42	6.40	***6.41***		6.15	6.20	***6.18***	
Treatment 5 Pre Rigor IB 1/4 RC	1							6.41	6.46	***6.44***		6.30	6.32	***6.31***	
	2	6.220	6.220	**6.220**	6.000	5.990	**5.995**	6.36	6.37	***6.37***	6.39	6.32	6.33	***6.33***	6.26
	3							6.35	6.40	***6.38***		6.09	6.22	***6.16***	

Table C.3. R-value - Replication 1

R-value

Sample Name		sample No.	trial No.	Before chilling Frozen muscle 250 nm	260 nm	r-value	avg	AFTER CHILLING Frozen muscle 250 nm	260 nm	r-value	avg
blank(ref.)											
Treatment 1	Post Rigor WC	1	1.1	0.3090	0.3170	0.9748	0.9569	0.3190	0.2630	1.2129	1.1780
			1.2	0.3240	0.3450	0.9391		0.3050	0.2550	1.1961	
		2	2.1	0.3740	0.4770	0.7841	0.7889	0.3220	0.3140	1.0255	
			2.2	0.3770	0.4750	0.7937		0.3530	0.3220	1.0963	
		3	3.1	0.3150	0.3920	0.8036	0.8871	0.3620	0.2860	1.2657	
			3.2	0.2980	0.3070	0.9707		0.3370	0.2650	1.2717	
Treatment 2	Pre Rigor IG	1	1.1	0.3670	0.4520	0.8119	0.8149				
			1.2	0.2920	0.3570	0.8179					
		2	2.1	0.3830	0.4620	0.8290	0.8392				
			2.2	0.2480	0.2920	0.8493					
		3	3.1	0.3540	0.4350	0.8138	0.8040				
			3.2	0.3900	0.4910	0.7943					
Treatment 3	Pre Rigor IG CO_2	1	1.1	0.3250	0.4100	0.7927	0.8051				
			1.2	0.3450	0.4220	0.8175					
		2	2.1	0.3400	0.4260	0.7981	0.8019				
			2.2	0.2820	0.3500	0.8057					
		3	3.1	0.4030	0.4760	0.8466	0.8334	**250 nm**	**260 nm**	**r-value**	**avg**
			3.2	0.3650	0.4450	0.8202					
Treatment 4	Pre Rigor IB RC	1	1.1	0.3600	0.4320	0.8333	0.8095	0.3620	0.3220	1.1242	0.9638
			1.2	0.3520	0.4480	0.7857		0.3350	0.3160	1.0601	
		2	2.1	0.3500	0.3770	0.9284	0.9017	0.3090	0.3600	0.8583	
			2.2	0.3150	0.3600	0.8750		0.3000	0.3620	0.8287	
		3	3.1	0.3290	0.3970	0.8287	0.8373	0.3460	0.3600	0.9611	
			3.2	0.3240	0.3830	0.8460		0.4990	0.5250	0.9505	
Treatment 5	Pre Rigor IB 1/4 RC	1	1.1	0.3580	0.4510	0.7938	0.8099	0.3270	0.4050	0.8074	0.8812
			1.2	0.3800	0.4600	0.8261		0.3830	0.4370	0.8764	
		2	2.1	0.3320	0.3900	0.8513	0.8571	0.3270	0.3450	0.9478	
			2.2	0.3150	0.3650	0.8630		0.2170	0.2660	0.8158	
		3	3.1	0.3610	0.4280	0.8435	0.8334	0.3240	0.3340	0.9701	
			3.2	0.3170	0.3850	0.8234		0.3330	0.3830	0.8695	

Table C.4. Sarcomere length – Replication 1

Sarcomere length

Study 1 - Replication 1 T= from center to the diffraction band

Sample Name	sample NO.	trial No.	D	T			SARCOMERE LENGTH	avg	avg
			mm	mm					
	No.1	No.1-1	100	32.10			2.07		
	No.1	No.1-2	100	34.90			1.92		
	No.1	No.1-3	100	32.40			2.05		
	No.1	No.1-4	100	34.30			1.95		
Post Rigor WC T1	No.1	No.1-5	100	34.10	35.58		1.96	1.90	
	No.1	No.1-6	100	39.10			1.74		
	No.1	No.1-7	100	33.60			1.99		
	No.1	No.1-8	100	38.50			1.76		
	No.1	No.1-9	100	40.10			1.70		
	No.1	No.1-10	100	36.70			1.84		
	No.2	No. 2-1	100	36.70			1.84		
	No.2	No. 2-2	100	39.10			1.74		
	No.2	No. 2-3	100	36.90			1.83		
	No.2	No. 2-4	100	37.70			1.79		
Post Rigor WC T1	No.2	No. 2-5	100	36.80	37.32	37.07	1.83	1.81	1.83
	No.2	No. 2-6	100	35.10			1.91		
	No.2	No. 2-7	100	36.90			1.83		
	No.2	No. 2-8	100	40.80			1.68		
	No.2	No. 2-9	100	38.30			1.77		
	No.2	No. 2-10	100	34.90			1.92		
	No.3	No. 3-1	100	37.20			1.81		
	No.3	No. 3-2	100	40.20			1.70		
	No.3	No. 3-3	100	36.50			1.85		
	No.3	No. 3-4	100	39.70			1.71		
Post Rigor WC T1	No.3	No. 3-5	100	41.50	38.31		1.65	1.78	
	No.3	No. 3-6	100	36.60			1.84		
	No.3	No. 3-7	100	39.40			1.73		
	No.3	No. 3-8	100	41.00			1.67		
	No.3	No. 3-9	100	31.40			2.11		
	No.3	No. 3-10	100	39.60			1.72		
	No.1	No.1-1	100	36.30					
	No.1	No.1-2	100	36.95					
	No.1	No.1-3	100	38.00					
	No.1	No.1-4	100	40.00			1.70		
T2 Pre Rigor IG	No.1	No.1-5	100	38.10	37.89			1.70	
	No.1	No.1-6	100	40.20			1.70		
	No.1	No.1-7	100	40.30			1.69		
	No.1	No.1-8	100	35.20					
	No.1	No.1-9	100	34.00					
	No.1	No.1-10	100	39.80			1.71		
	No.2	No. 2-1	100	40.70			1.68		
	No.2	No. 2-2	100	38.60					
	No.2	No. 2-3	100	41.00			1.67		
	No.2	No. 2-4	100	43.00			1.60		
T2 Pre Rigor IG	No.2	No. 2-5	100	38.70	40.85	39.61		1.63	1.65
	No.2	No. 2-6	100	37.80					
	No.2	No. 2-7	100	41.75			1.64		
	No.2	No. 2-8	100	40.75			1.68		
	No.2	No. 2-9	100	39.55					
	No.2	No. 2-10	100	46.60			1.50		
	No.3	No. 3-1	100	41.20			1.66		
	No.3	No. 3-2	100	37.70					
	No.3	No. 3-3	100	37.60					
	No.3	No. 3-4	100	43.90			1.57		
T2 Pre Rigor IG	No.3	No. 3-5	100	42.10	40.09		1.63	1.61	
	No.3	No. 3-6	100	43.85			1.58		
	No.3	No. 3-7	100	38.00					
	No.3	No. 3-8	100	36.45					
	No.3	No. 3-9	100	42.60			1.61		
	No.3	No. 3-10	100	37.50					

Table C.4. (contd')

	No.1	No.1-1	100	41.60			1.65		
	No.1	No.1-2	100	43.65			1.58		
	No.1	No.1-3	100	36.55					
	No.1	No.1-4	100	40.60			1.68		
T3 Pre Rigor IG CO_2	No.1	No.1-5	100	41.95	41.47		1.64	1.62	
	No.1	No.1-6	100	37.20					
	No.1	No.1-7	100	43.60			1.58		
	No.1	No.1-8	100	43.60			1.58		
	No.1	No.1-9	100	45.65			1.52		
	No.1	No.1-10	100	40.30			1.69		
	No.2	No. 2-1	100	34.40					
	No.2	No. 2-2	100	36.30					
	No.2	No. 2-3	100	38.40					
	No.2	No. 2-4	100	40.70			1.68		
T3 Pre Rigor IG CO_2	No.2	No. 2-5	100	42.40	37.93	38.65	1.62	1.63	1.65
	No.2	No. 2-6	100	41.10			1.66		
	No.2	No. 2-7	100	36.10					
	No.2	No. 2-8	100	33.00					
	No.2	No. 2-9	100	32.50					
	No.2	No. 2-10	100	44.40			1.56		
	No.3	No. 3-1	100	33.30					
	No.3	No. 3-2	100	33.70					
	No.3	No. 3-3	100	35.35					
	No.3	No. 3-4	100	34.40					
T3 Pre Rigor IG CO_2	No.3	No. 3-5	100	39.50	36.55		1.72	1.70	
	No.3	No. 3-6	100	33.10					
	No.3	No. 3-7	100	41.10			1.66		
	No.3	No. 3-8	100	38.80			1.75		
	No.3	No. 3-9	100	35.60					
	No.3	No. 3-10	100	40.60			1.68		
	No.1	No.1-1	100	40.10			1.70		
	No.1	No.1-2	100	33.10			2.01		
	No.1	No.1-3	100	35.80			1.88		
	No.1	No.1-4	100	34.20			1.96		
T4 Pre Rigor IB RC (WED DEC 7 2011)	No.1	No.1-5	100	40.50	36.41		1.69	1.86	
	No.1	No.1-6	100	34.10			1.96		
	No.1	No.1-7	100	37.60			1.80		
	No.1	No.1-8	100	36.70			1.84		
	No.1	No.1-9	100	37.60			1.80		
	No.1	No.1-10	100	34.40			1.95		
	No.2	No. 2-1	100	39.70			1.71		
	No.2	No. 2-2	100	42.60			1.61		
	No.2	No. 2-3	100	38.20			1.77		
	No.2	No. 2-4	100	41.60			1.65		
T4 Pre Rigor IB RC (WED DEC 7 2011)	No.2	No. 2-5	100	38.70	38.91	37.36	1.75	1.75	1.82
	No.2	No. 2-6	100	42.10			1.63		
	No.2	No. 2-7	100	38.40			1.77		
	No.2	No. 2-8	100	36.30			1.85		
	No.2	No. 2-9	100	35.20			1.91		
	No.2	No. 2-10	100	36.30			1.85		
	No.3	No. 3-1	100	39.50			1.72		
	No.3	No. 3-2	100	31.80			2.09		
	No.3	No. 3-3	100	36.20			1.86		
	No.3	No. 3-4	100	35.20			1.91		
T4 Pre Rigor IB RC (WED DEC 7 2011)	No.3	No. 3-5	100	39.20	36.75		1.73	1.85	
	No.3	No. 3-6	100	31.60			2.10		
	No.3	No. 3-7	100	34.80			1.93		
	No.3	No. 3-8	100	38.00			1.78		
	No.3	No. 3-9	100	39.80			1.71		
	No.3	No. 3-10	100	41.40			1.65		
	No.1	No.1-1	100	38.00			1.78		
	No.1	No.1-2	100	42.10			1.63		
	No.1	No.1-3	100	39.50			1.72		
	No.1	No.1-4	100	37.40			1.81		
T5 Pre Rigor IB 1/4 RC (WED DEC 7 2011)	No.1	No.1-5	100	38.70	38.33		1.75	1.77	
	No.1	No.1-6	100	37.50			1.80		
	No.1	No.1-7	100	35.80			1.88		
	No.1	No.1-8	100	35.40			1.90		
	No.1	No.1-9	100	38.20			1.77		
	No.1	No.1-10	100	40.70			1.68		
	No.2	No. 2-1	100	37.30			1.81		
	No.2	No. 2-2	100	34.90			1.92		
	No.2	No. 2-3	100	38.30			1.77		
	No.2	No. 2-4	100	41.10			1.66		
T5 Pre Rigor IB 1/4 RC (WED DEC 7 2011)	No.2	No. 2-5	100	37.10	37.48	37.76	1.82	1.81	1.80
	No.2	No. 2-6	100	38.20			1.77		
	No.2	No. 2-7	100	36.20			1.86		
	No.2	No. 2-8	100	36.80			1.83		
	No.2	No. 2-9	100	34.80			1.93		
	No.2	No. 2-10	100	40.10			1.70		
	No.3	No. 3-1	100	39.80			1.71		
	No.3	No. 3-2	100	37.10			1.82		
	No.3	No. 3-3	100	34.30			1.95		
	No.3	No. 3-4	100	33.20			2.01		
T5 Pre Rigor IB 1/4 RC (WED DEC 7 2011)	No.3	No. 3-5	100	38.20	37.46		1.77	1.81	
	No.3	No. 3-6	100	40.00			1.70		
	No.3	No. 3-7	100	35.10			1.91		
	No.3	No. 3-8	100	36.20			1.86		
	No.3	No. 3-9	100	40.60			1.68		
	No.3	No. 3-10	100	40.10			1.70		

Table C.5. Fragmentation index – Replication 1

GFI Study 1 - Replication 1					1000		
sample name	No.	Wt dried screen	Wt wet sample	Wt dried sample + screen	wt dried sample		AVG
Treatment 1 Post rigor WC	1.1	0.3293	4.34	1.0732	0.7439	171.41	182.14
	1.2	0.3295	4.5	1.1435	0.814	180.89	
	2.1	0.3351	4.57	1.2075	0.8724	190.90	
	2.2	0.3382	4.37	1.2258	0.8876	203.11	
	3.1	0.328	4.96	1.3004	0.9724	196.05	
	3.2	0.3146	4.64	1.0128	0.6982	150.47	
Treatment 2 Pre rigor IG	1.1	0.3239	4.53	1.1076	0.7837	173.00	171.50
	1.2	0.3208	4.47	1.0452	0.7244	162.06	
	2.1	0.3332	4.4	0.7718	0.4386	99.68	
	2.2	0.3217	4.49	1.1639	0.8422	187.57	
	3.1	0.3223	4.59	1.2216	0.8993	195.93	
	3.2	0.3224	4.63	1.2981	0.9757	210.73	
Treatment 3 Pre rigor IG CO_2	1.1	0.3312	4.4	1.2111	0.8799	199.98	202.49
	1.2	0.3259	4.58	1.2108	0.8849	193.21	
	2.1	0.3259	4.64	1.2913	0.9654	208.06	
	2.2	0.3308	4.52	1.3111	0.9803	216.88	
	3.1	0.3323	4.52	1.2454	0.9131	202.01	
	3.2	0.323	4.55	1.2093	0.8863	194.79	
Treatment 4 Pre rigor IB RC	1.1	0.6783	4.8	1.6601	0.9818	204.54	190.67
	1.2	0.6793	4.71	1.6476	0.9683	205.58	
	2.1	0.6903	4.73	1.6199	0.9296	196.53	
	2.2	0.7051	4.8	1.6043	0.8992	187.33	
	3.1	0.7236	5	1.5946	0.871	174.20	
	3.2	0.7331	4.91	1.5963	0.8632	175.80	
Treatment 5 Pre Rigor IB RC 1/4	1.1	0.7188	4.66	1.5329	0.8141	174.70	177.95
	1.2	0.7414	4.4	1.6224	0.881	200.23	
	2.1	0.6735	4.91	1.5382	0.8647	176.11	
	2.2	0.6809	4.79	1.4444	0.7635	159.39	
	3.1	0.6807	4.93	1.5476	0.8669	175.84	
	3.2	0.677	4.86	1.5588	0.8818	181.44	

Table C.6. Cooking yield – Replication 1

Cooking Yield Study 1 Replication 1								
Sample Name	No.	tube no.	wt tube before stuffing	wt tube + batter before cooking	wt empty tube after cooking	wt gel after cooking	Cooking yield (%)	Average
			g	g	g	g		
T1 Post Rigor WC	1	1	183.41	237.92	185.92	45.14	87.42%	88.10%
	2	2	183.02	237.46	187.23	45.85	91.95%	
	3	3	183.67	238.08	185.15	45.86	87.01%	
	4	4	183.95	238.05	185.67	45.55	87.38%	
	5	5	182.77	237.25	184.80	45.22	86.73%	
T1 FAILED Post Rigor WC	1	11	183.14	240.11	186.53	47.51	89.35%	87.81%
	2	12	182.99	239.07	185.09	46.68	86.98%	
	3	13	183.54	240.70	186.83	46.69	87.44%	
	4	14	182.83	237.42	184.75	46.18	88.11%	
	5	15	183.44	241.27	186.30	47.55	87.17%	
T2 Pre Rigor IG	1	1	183.07	239.33	185.26	48.45	90.01%	90.10%
	2	2	182.69	237.38	184.11	46.19	87.05%	
	3	3	183.30	237.40	186.00	47.68	93.12%	
	4	4	183.71	238.13	189.47	43.06	89.71%	
	5	5	183.76	238.05	184.28	48.66	90.59%	
T3 Pre Rigor IG CO_2	1	6	184.03	242.90	187.54	47.78	87.12%	90.79%
	2	7	183.05	237.91	184.32	49.83	93.15%	
	3	8	183.07	238.01	185.58	48.27	92.43%	
	4	9	182.95	237.63	189.17	44.18	92.17%	
	5	10	183.73	238.08	184.47	47.67	89.07%	
T4 Pre Rigor IB RC	1	11	183.07	237.85	188.64	43.20	89.03%	88.75%
	2	12	182.53	237.11	183.75	45.10	84.87%	
	3	13	183.34	240.75	184.57	49.66	88.64%	
	4	14	182.78	237.22	185.25	45.74	88.56%	
	5	15	183.80	238.73	193.60	41.09	92.65%	
T5 Pre Rigor IB 1/4 RC	1	16	183.27	237.75	184.91	47.98	91.08%	91.44%
	2	17	183.97	239.35	188.04	46.70	91.68%	
	3	18	183.15	240.61	187.59	48.80	92.66%	
	4	19	184.02	238.62	185.73	48.12	91.26%	
	5	20	184.29	238.97	185.46	48.32	90.51%	

Table C.7. Torsion test – Replication 1

Torsion Test

Study 1 - replication 1

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC	Post Rigor WC	1	19.32	7.7	30.56	0.99	31.74	1.10
		2	20.81	9.2	32.92	1.20		
		3	19.42	10.5	30.72	1.41	29.96	1.39
		4	18.46	10.2	29.20	1.37		
		5	19.42	10.1	30.72	1.35	27.65	1.43
		6	15.54	10.9	24.58	1.50		
		7	17.47	10.1	27.64	1.37	25.43	1.38
		8	14.68	10.1	23.22	1.39		
		9	18.46	7.6	29.20	0.98	29.20	0.98
T1 FAILEDPost Rigor WC	Post Rigor WC failed	1	21.19	9.20	33.52	1.20	29.40	1.49
		2	15.98	12.80	25.28	1.78		
		3	18.4	11.00	29.11	1.49	30.45	1.44
		4	20.1	10.40	31.80	1.39		
		5	19.15	11.40	30.30	1.55	33.63	1.57
		6	23.37	12.00	36.97	1.60		
		7	22.79	9.90	36.05	1.29	35.04	1.45
		8	21.51	11.90	34.03	1.60		
		9	15.03	8.40	23.78	1.13	27.04	1.15
		10	19.15	8.90	30.30	1.17		
T2 Pre Rigor IG	Pre Rigor IG	1	24.65	13.00	39.00	1.74	32.34	1.50
		2	16.24	9.30	25.69	1.26		
		3	18.02	9.70	28.51	1.30	30.68	1.57
		4	20.77	13.40	32.86	1.83		
		5	18.33	10.10	29.00	1.36	29.99	1.56
		6	19.59	12.80	30.99	1.75		
		7	19.14	10.70	30.28	1.44	33.63	1.57
		8	23.37	12.70	36.97	1.71		
		9	16.14	11.10	25.53	1.53	26.25	1.45
		10	17.05	10.10	26.97	1.37		
T3 Pre Rigor IG CO_2	Pre Rigor IG CO_2	1	20.27	12.80	32.07	1.75	32.56	1.59
		2	20.89	10.80	33.05	1.44		
		3	24.1	12.50	38.13	1.67	37.75	1.59
		4	23.62	11.40	37.37	1.51		
		5	17.43	9.40	27.57	1.26	27.57	1.26
		6						
		7	20.32	10.80	32.15	1.45	32.62	1.52
		8	20.92	11.80	33.10	1.59		
		9	16.86	8.70	26.67	1.16	29.31	1.42
		10	20.19	12.40	31.94	1.69		
T4 Pre Rigor IB RC	Pre Rigor IB RC	1	24.56	11.80	38.85	1.56	36.69	1.38
		2	21.83	9.20	34.54	1.19		
		3	31.93	12.40	50.51	1.59	35.18	1.50
		4	12.54	10.10	19.84	1.41		
		5	26.73	10.20	42.29	1.30	45.97	1.48
		6	31.39	12.80	49.66	1.65		
		7	30.81	13.60	48.74	1.78	47.95	1.59
		8	29.81	11.00	47.16	1.40		
		9	31.13	12.30	49.25	1.58	42.66	1.54
		10	22.8	11.30	36.07	1.50		
T5 Pre Rigor IB 1/4 RC	Pre Rigor IB 1/4 RC	1	29.62	11.9	46.86	1.53	45.98	1.60
		2	28.51	12.7	45.10	1.66		
		3	39.89	12.4	63.11	1.52	52.21	1.50
		4	26.12	11.4	41.32	1.49		
		5	32.21	13.6	50.96	1.77	53.58	1.62
		6	35.53	11.8	56.21	1.47		
		7	33.20	14.5	52.52	1.89	61.21	1.76
		8	44.18	13.3	69.89	1.62		
		9	34.35	12.4	54.34	1.57	57.37	1.84
		10	38.18	16.3	60.40	2.12		

Table C.8. Temperature monitoring – Replication 2

Temperature and Humidity

Date: july / 13 / 2011

Study 1 - replication 2

Time interval	Post Rigor WC For carcass	Water Temp. ©	Pre Rigor IB For carcass	Chilling room Temp. ©	Chilling room Humidity (%)	Pre Rigor IB 1/4 For carcass	Chilling room Temp. ©	Chilling room Humidity (%)
0	40.70		39.30	-18.6		39.7	-27.1	73.3%
5	40.40	-0.40	36.50	-18.4	23.4%	38.3	-26.9	74.4%
10	40.20	-0.50	34.40	-22.2	36.1%	32	-25.9	76.9%
15	39.50	-0.40	32.50	-24.8	54.5%	28	-26	74.1%
20	38.50	-0.50	30.80	-25.9	61.8%	24.3	-26	75.8%
25	37.50	-0.50	28.80	-26.1	73.5%	21	-26.3	74.6%
30	36.30	-0.50	26.60	-26.1	67.9%	17.9	-26.4	74.9%
35	35.10	-0.50	24.30	-26.5	66.7%	15	-24.7	78.0%
40	34.20	-0.50	22.60	-27.2	71.7%	12.2	-25.8	75.1%
45	32.90	-0.60	20.70	-27.5	70.1%	9.9	-26.2	74.2%
50	31.60	-0.50	18.40	-26.2	68.9%	7.6	-26.8	73.3
55	30.40	-0.50	16.70	-25.2	68.5%	5.6	-26.9	72.9
60	29.10	-0.50	14.90	-25.4	68.5%	4.2	-26.8	74.1
65	28.20	-0.40	13.10	-25.7	68.5%	3.6	-26.7	74.5
70	27.10	-0.40	11.20	-0.27	72.0%			75.1%
75	25.80	-0.40	9.90	-26	74.4%			
80	24.50	-0.50	8.30	-25.9	76.9			
85	23.40	-0.50	6.60	-26.6	74.1%			
90	22.20	-0.50	5.50	-26	75.8%			
95	21.20	-0.5	4.30	-26.3	74.6%			
100	20.10	-0.40	3.20	-26.6	74.9%			
105	19.10	-0.40			446.8%			
110	18.30	-0.40						
115	17.50	-0.40						
120	16.60	-0.50						
125	15.70	-0.50						
130	15.10	-0.50						
135	14.40	-0.40						
140	13.90	-0.40						
145	13.50	-0.40						
150	12.60	-0.40						
155	12.00	-0.40						
160	11.50	-0.40						
165	10.90	-0.40						
170	10.50	-0.50						
175	10.10	-0.50						
180	9.50	-0.50						
185	9.10	-0.50						
190	8.70	-0.50						
195	8.30	-0.50						
200	7.90	-0.50						
205	7.60	-0.50						
210	7.20	-0.50						
215	7.00	-0.50						
220	6.50	-0.40						
225	6.20	-0.40						
230	5.90	-0.40						
235	5.70	-0.40						
240	5.50	-0.40						
245	5.30	-0.40						
250	5.10	-0.40						
255	4.90	-0.40						
260	4.70	-0.40						
265	4.50	-0.40						
270	4.30	0.40						
275	4.10	0.40						
280	4.00	0.40						
285	3.70	0.4						

Table C.9. Batter and raw meat pH – Replication 2

pH

Date: july / 27 / 2011

modifications mande rep de

Sample Name		batter before overnight			batter after overnight			frozen raw meat before chilling				frozen raw meat after chilling			
		rep 1	rep 2	avg	rep 1	rep 2	*avg*	rep 1	rep 2	*avg*	avg	rep 1	rep 2	*avg*	avg
Treatment 1 Post Rigor WC	1	5.90	5.90	**5.90**	5.92	5.92	**5.92**					5.88	5.94	***5.91***	5.81
	2											5.80	5.83	***5.82***	
	3											5.57	5.81	***5.69***	
Treatment 2 Pre Rigor IG	1	6.02	6.03	**6.03**	6.03	6.04	**6.04**		5.91	***5.91***	6.08				
	2							6.29	6.14	***6.22***					
	3							6.08	6.15	***6.12***					
Treatment 3 Pre Rigor IG CO_2	1	6.14	6.15	**6.15**	6.17	6.19	**6.18**	6.15	6.27	***6.21***	5.93				
	2							5.81	5.92	***5.87***					
	3							5.70	5.73	***5.72***					
Treatment 4 Pre Rigor IB RC MON DEC 5	1	5.95	5.94	**5.95**	5.94	5.94	**5.94**	5.95	5.89	5.92	6.00	5.78	5.72	5.75	5.84
	2							5.90	5.93	5.92		5.77	5.83	5.80	
	3							6.20	6.12	6.16		5.96	5.95	5.96	
Treatment 5 Pre Rigor IB 1/4 RC MON DEC 5	1	5.95	5.95	**5.95**	5.97	5.97	**5.97**	6.15	6.24	6.20	6.27	5.91	5.91	5.91	5.94
	2							6.32	6.41	6.37		5.94	5.99	5.97	
	3							6.21	6.30	6.26		5.91	5.96	5.94	

Table C.10. R-value - Replication 2

R-value										
Date: july / 27 / 2011			sample 3 g, wave leth, 250 and 260 nm				changes done/ rep dec 2011			
Study 1 - replication 2			frozen muscle before chilling				frozen muscle after chilling			
Sample Name	**sample No.**	**trial No.**	**250 nm**	**260 nm**	**r-value**	**avg**	**250 nm**	**260 nm**	**r-value**	**avg**
blank(ref.)			**0.096**	**0.056**						
Treatment 1 Post Rigor WC	1	1.1					0.5670	0.4350	1.303448276	1.3494
		1.2					0.6940	0.5280	1.314393939	
	2	2.1					0.6440	0.4550	1.415384615	
		2.2					0.6460	0.4560	1.416666667	
	3	3.1					0.5530	0.4180	1.322966507	
		3.2					0.5440	0.4110	1.323600973	
Treatment 2 Pre Rigor IG	1	1.1	0.5640	0.4440	1.27027027	1.2726				
		1.2	0.5610	0.4400	1.275					
	2	2.1	0.5700	0.5670	1.005291005	1.0162				
		2.2	0.6450	0.6280	1.027070064					
	3	3.1	0.4710	0.4260	1.105633803	1.0839				
		3.2	0.5640	0.5310	1.062146893					
Treatment 3 Pre Rigor IG CO_2	1	1.1	0.5590	0.5570	1.003590664	1.0288				
		1.2	0.5660	0.5370	1.054003724					
	2	2.1	0.5960	0.5910	1.008460237	1.0138				
		2.2	0.5860	0.5750	1.019130435					
	3	3.1	0.5480	0.3850	1.423376623	1.4355				
		3.2	0.5400	0.3730	1.44772118					
Treatment 4 Pre Rigor IB RC	1	1.1	0.3610	0.3040	1.1875	1.1833	0.3910	0.2950	1.325423729	1.2564
		1.2	0.3620	0.3070	1.179153094		0.3400	0.2520	1.349206349	
	2	2.1	0.3520	0.3070	1.146579805	1.1450	0.3290	0.2530	1.300395257	
		2.2	0.3430	0.3000	1.143333333		0.3280	0.2550	1.28627451	
	3	3.1	0.3700	0.4090	0.904645477	0.8910	0.3780	0.3280	1.152439024	
		3.2	0.3220	0.3670	0.877384196		0.3970	0.3530	1.124645892	
Treatment 5 Pre Rigor IB 1/4 RC	1	1.1	0.3530	0.3440	1.026162791	0.9674	0.3740	0.3130	1.194888179	1.1594
		1.2	0.3780	0.4160	0.908653846		0.3550	0.3030	1.171617162	
	2	2.1	0.3680	0.4590	0.801742919	0.8034	0.4020	0.3910	1.028132992	
		2.2	0.3470	0.4310	0.805104408		0.3770	0.3430	1.099125364	
	3	3.1	0.3100	0.3390	0.914454277	0.9089	0.3390	0.2830	1.197879859	
		3.2	0.3270	0.3620	0.903314917		0.3490	0.2760	1.264492754	

Table C.11. Sarcomere Length - Replication 2

Sarcomere length | **tudy 1 - replication 2** | SUMMER 2011/WINTER 2011 w/corr for T4 & T5 | 0.6328

Date: july / 28 / 2011   T= from center to the diffraction band

Sample Name	sample NO	trial No.	D	T	avg		SARCOMERE LENGTH	AVG	AVG
			mm	mm			MICROMETERS		
	No.1	No.1-1	100	43.20			1.60		
	No.1	No.1-2	100	42.45			1.62		
	No.1	No.1-3	100	39.70			1.71		
	No.1	No.1-4	100	40.30			1.69		
Post Rigor WC T1	No.1	No.1-5	100	38.30	40.64		1.77	1.68	
	No.1	No.1-6	100	42.00			1.63		
	No.1	No.1-7	100	39.00			1.74		
	No.1	No.1-8	100	41.50			1.65		
	No.1	No.1-9	100	41.80			1.64		
	No.1	No.1-10	100	38.10			1.78		
	No.2	No. 2-1	100	33.90			1.97		
	No.2	No. 2-2	100	32.80			2.03		
	No.2	No. 2-3	100	35.90			1.87		
	No.2	No. 2-4	100	32.40			2.05		
Post Rigor WC T1	No.2	No. 2-5	100	31.60	34.09		2.10	1.98	1.81
	No.2	No. 2-6	100	36.20			1.86		
	No.2	No. 2-7	100	31.30			2.12		
	No.2	No. 2-8	100	31.20			2.12		
	No.2	No. 2-9	100	44.20			1.57		
	No.2	No. 2-10	100	31.40			2.11		
	No.3	No. 3-1	100	40.30			1.69		
	No.3	No. 3-2	100	35.20			1.91		
	No.3	No. 3-3	100	43.10			1.60		
	No.3	No. 3-4	100	38.80			1.75		
Post Rigor WC T1	No.3	No. 3-5	100	40.30	38.82		1.69	1.75	
	No.3	No. 3-6	100	37.30			1.81		
	No.3	No. 3-7	100	39.70			1.71		
	No.3	No. 3-8	100	35.20			1.91		
	No.3	No. 3-9	100	39.50			1.72		
	No.3	No. 3-10	100	38.80			1.75		
	No.1	No.1-1	100	39.80			1.71		
	No.1	No.1-2	100	40.00			1.70		
	No.1	No.1-3	100	37.65					
	No.1	No.1-4	100	34.20					
T2 Pre Rigor IG	No.1	No.1-5	100	37.50	37.76			1.67	
	No.1	No.1-6	100	44.60			1.55		
	No.1	No.1-7	100	31.60					
	No.1	No.1-8	100	35.00					
	No.1	No.1-9	100	40.10			1.70		
	No.1	No.1-10	100	37.10					
	No.2	No. 2-1	100	41.50			1.65		
	No.2	No. 2-2	100	38.90			1.75		
	No.2	No. 2-3	100	40.30			1.69		
	No.2	No. 2-4	100	41.40			1.65		
T2 Pre Rigor IG	No.2	No. 2-5	100	37.70	39.72			1.67	1.66
	No.2	No. 2-6	100	35.10					
	No.2	No. 2-7	100	37.70					
	No.2	No. 2-8	100	39.20			1.73		
	No.2	No. 2-9	100	41.60			1.65		
	No.2	No. 2-10	100	43.80			1.58		
	No.3	No. 3-1	100	38.30					
	No.3	No. 3-2	100	43.20			1.60		
	No.3	No. 3-3	100	41.20			1.66		
	No.3	No. 3-4	100	38.30					
T2 Pre Rigor IG	No.3	No. 3-5	100	38.30	40.14			1.64	
	No.3	No. 3-6	100	40.00					
	No.3	No. 3-7	100	42.60			1.61		
	No.3	No. 3-8	100	40.90			1.67		
	No.3	No. 3-9	100	37.40					
	No.3	No. 3-10	100	41.20			1.66		

Table C.11. (cont'd)

T3 Pre Rigor IG CO_2	No.1	No.1-1	100	53.30	56.57		1.35	1.31	1.39
	No.1	No.1-2	100	55.20			1.31		
	No.1	No.1-3	100	61.00					
	No.1	No.1-4	100	52.10			1.37		
	No.1	No.1-5	100	59.50			1.24		
	No.1	No.1-6	100	58.00			1.26		
	No.1	No.1-7	100	61.40					
	No.1	No.1-8	100	59.50			1.24		
	No.1	No.1-9	100	57.20			1.27		
	No.1	No.1-10	100	48.50			1.45		
T3 Pre Rigor IG CO_2	No.2	No. 2-1	100	61.30	56.81			1.30	
	No.2	No. 2-2	100	52.90			1.35		
	No.2	No. 2-3	100	57.00			1.28		
	No.2	No. 2-4	100	56.50			1.29		
	No.2	No. 2-5	100	52.20			1.37		
	No.2	No. 2-6	100	52.60			1.36		
	No.2	No. 2-7	100	59.30			1.24		
	No.2	No. 2-8	100	59.20			1.24		
	No.2	No. 2-9	100	59.70					
	No.2	No. 2-10	100	57.40			1.27		
T3 Pre Rigor IG CO_2	No.3	No. 3-1	100	49.00	40.49		1.44	1.55	
	No.3	No. 3-2	100	38.10					
	No.3	No. 3-3	100	49.20			1.43		
	No.3	No. 3-4	100	36.60					
	No.3	No. 3-5	100	34.70					
	No.3	No. 3-6	100	31.40					
	No.3	No. 3-7	100	38.30					
	No.3	No. 3-8	100	41.00			1.67		
	No.3	No. 3-9	100	41.60			1.65		
	No.3	No. 3-10	100	45.00			1.54		
T4 Pre Rigor IB RC (MON DEC 5 2011) (after chilling)	No.1	No.1-1	100	41.60	40.17	38.46	1.65	1.70	1.85
	No.1	No.1-2	100	39.20			1.73		
	No.1	No.1-3	100	40.50			1.69		
	No.1	No.1-4	100	36.40			1.85		
	No.1	No.1-5	100	46.00			1.51		
	No.1	No.1-6	100	38.30			1.77		
	No.1	No.1-7	100	41.60			1.65		
	No.1	No.1-8	100	40.40			1.69		
	No.1	No.1-9	100	38.80			1.75		
	No.1	No.1-10	100	38.90			1.75		
T4 Pre Rigor IB RC (MON DEC 5 2011) (after chilling)	No.2	No. 2-1	100	34.70	34.71		1.93	1.94	
	No.2	No. 2-2	100	30.20			2.19		
	No.2	No. 2-3	100	35.20			1.91		
	No.2	No. 2-4	100	34.80			1.93		
	No.2	No. 2-5	100	34.70			1.93		
	No.2	No. 2-6	100	31.40			2.11		
	No.2	No. 2-7	100	35.20			1.91		
	No.2	No. 2-8	100	38.30			1.77		
	No.2	No. 2-9	100	35.20			1.91		
	No.2	No. 2-10	100	37.40			1.81		
T4 Pre Rigor IB RC (MON DEC 5 2011) (after chilling)	No.3	No. 3-1	100	34.70	35.35		1.93	1.90	
	No.3	No. 3-2	100	33.10			2.01		
	No.3	No. 3-3	100	39.40			1.73		
	No.3	No. 3-4	100	33.50			1.99		
	No.3	No. 3-5	100	36.20			1.86		
	No.3	No. 3-6	100	34.00			1.97		
	No.3	No. 3-7	100	35.00			1.92		
	No.3	No. 3-8	100	35.90			1.87		
	No.3	No. 3-9	100	37.90			1.79		
	No.3	No. 3-10	100	33.80			1.98		
T5 Pre Rigor IB 1/4 RC (MON DEC 5 2011) (after chilling)	No.1	No.1-1	100	39.70	34.32	35.18	1.71	1.96	1.91
	No.1	No.1-2	100	38.10			1.78		
	No.1	No.1-3	100	35.20			1.91		
	No.1	No.1-4	100	34.40			1.95		
	No.1	No.1-5	100	31.20			2.12		
	No.1	No.1-6	100	31.70			2.09		
	No.1	No.1-7	100	31.10			2.13		
	No.1	No.1-8	100	32.70			2.04		
	No.1	No.1-9	100	34.10			1.96		
	No.1	No.1-10	100	35.00			1.92		
T5 Pre Rigor IB 1/4 RC (MON DEC 5 2011) (after chilling)	No.2	No. 2-1	100	36.20	35.27		1.86	1.91	
	No.2	No. 2-2	100	35.10			1.91		
	No.2	No. 2-3	100	35.80			1.88		
	No.2	No. 2-4	100	36.60			1.84		
	No.2	No. 2-5	100	34.90			1.92		
	No.2	No. 2-6	100	33.10			2.01		
	No.2	No. 2-7	100	35.20			1.91		
	No.2	No. 2-8	100	33.10			2.01		
	No.2	No. 2-9	100	37.80			1.79		
	No.2	No. 2-10	100	34.90			1.92		
T5 Pre Rigor IB 1/4 RC (MON DEC 5 2011) (after chilling)	No.3	No. 3-1	100	36.20	35.94		1.86	1.87	
	No.3	No. 3-2	100	35.10			1.91		
	No.3	No. 3-3	100	37.50			1.80		
	No.3	No. 3-4	100	36.30			1.85		
	No.3	No. 3-5	100	35.10			1.91		
	No.3	No. 3-6	100	33.80			1.98		
	No.3	No. 3-7	100	33.40			2.00		
	No.3	No. 3-8	100	38.70			1.75		
	No.3	No. 3-9	100	35.00			1.92		
	No.3	No. 3-10	100	38.30			1.77		

Table C.12. Fragmentation index - Replication 2

GFI Date: aug / 1 / 2011					Study 1 - replication 2 1000		
sample name	No.	Wt dried screen	Wt wet sample	Wt dried sample + screen	wt dried sample	GFI	avg
Treatment 1 Post rigor WC	1.1	0.3236	5.01	0.9513	0.6277	125.2894	168.2305
	1.2	0.3287	5	1.2221	0.8934	178.6800	
	2.1	0.3176	4.87	1.1894	0.8718	179.0144	
	2.2	0.3333	4.84	1.1837	0.8504	175.7025	
	3.1	0.3268	4.81	1.188	0.8612	179.0437	
	3.2	0.3225	4.9	1.1636	0.8411	171.6531	
Treatment 2 Pre rigor IG	1.1	0.3231	4.85	1.2297	0.9066	186.9278	193.6518
	1.2	0.3267	4.8	1.2167	0.8900	185.4167	
	2.1	0.3256	4.93	1.3569	1.0313	209.1886	
	2.2	0.3204	4.88	1.2934	0.9730	199.3852	
	3.1	0.329	4.9	1.2442	0.9152	186.7755	
	3.2	0.321	4.98	1.2882	0.9672	194.2169	
Treatment 3 Pre rigor IG CO_2	1.1	0.3352	4.94	1.0672	0.7320	148.1781	180.9385
	1.2	0.3269	4.79	1.2645	0.9376	195.7411	
	2.1	0.3185	4.74	1.0725	0.7540	159.0717	
	2.2	0.746	4.85	1.6827	0.9367	193.1340	
	3.1	0.7527	4.98	1.723	0.9703	194.8394	
	3.2	0.7077	4.8	1.6421	0.9344	194.6667	
Treatment 4 Pre rigor IB RC	1.1	0.7071	4.72	1.6732	0.9661	204.6822	193.5885
	1.2	0.6981	4.92	1.5707	0.8726	177.3577	
	2.1	0.71	4.98	1.7376	1.0276	206.3454	
	2.2	0.7238	4.81	1.7509	1.0271	213.5343	
	3.1	0.6763	4.76	1.5043	0.8280	173.9496	
	3.2	0.6782	4.91	1.5898	0.9116	185.6619	
Treatment 5 Pre Rigor IB RC 1/4	1.1	0.6903	4.82	1.593	0.9027	187.2822	199.6415
	1.2	0.6932	4.96	1.5873	0.8941	180.2621	
	2.1	0.7069	4.86	1.6926	0.9857	202.8189	
	2.2	0.7208	4.71	1.7334	1.0126	214.9894	
	3.1	0.7325	4.81	1.7492	1.0167	211.3721	
	3.2	0.7358	4.98	1.7374	1.0016	201.1245	

Table C.13. Cooking yield - Replication 2

Cooking Yield (Breast for shear force)								
STUDY 1 - REPLICATION 2 Date: july / 14- 15 / 2011								
Sample Name	No.	tube no.	wt tube before stuffing	wt tube + batter before cooking	wt empty tube after cooking	wt gel after cooking	Cooking yield (%)	Average
			g	g	g	g		
T1 Post Rigor WC	1	1	183.13	237.33	183.92	45.58	85.55%	86.56%
	2	2	183.28	238.59	188.25	42.35	85.55%	
	3	3	182.94	237.41	184.85	47.16	90.09%	
	4	4	184.52	239.64	186.16	45.69	85.87%	
	5	5	183.90	238.01	185.72	44.56	85.71%	
T1 FAILED Post Rigor WC	1	1	182.93	237.76	185.91	44.13	85.92%	83.89%
	2	2	183.48	239.92	184.78	48.37	88.00%	
	3	3	183.30	236.78	184.59	41.19	79.43%	
	4	4	183.05	237.21	184.26	43.32	82.22%	
	5							
T2 Pre Rigor IG	1	5	183.53	238.54	186.04	46.28	88.69%	88.51%
	2	6	184.05	239.38	194.01	39.49	89.37%	
	3	7	182.85	237.60	184.67	45.65	86.70%	
	4	8	183.40	237.77	184.79	47.14	89.26%	
	5							
T3 Pre Rigor IG CO_2	1	9	183.44	239.71	184.96	49.14	90.03%	91.22%
	2	10	183.10	237.09	184.22	48.56	92.02%	
	3	11	182.92	239.24	186.81	49.16	94.19%	
	4	12	183.87	242.00	184.82	50.57	88.63%	
	5							
T4 Pre Rigor IB RC	1	13	182.82	236.84	183.69	46.94	88.50%	90.04%
	2	14	182.98	238.64	184.09	49.65	91.20%	
	3	15	183.12	237.67	187.97	44.23	89.97%	
	4	16	183.56	239.17	185.83	48.04	90.47%	
	5							
T5 Pre Rigor IB 1/4 RC	1	17	183.95	237.61	185.55	47.23	91.00%	90.85%
	2	18	183.23	237.68	184.35	47.99	90.19%	
	3	19	182.99	237.56	185.92	46.92	91.35%	
	4	20						
	5							

Table C.14. Torsion test – Replication 2

Torsion Test

Date: july / 14-15 / 2011

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC	Post Rigor WC	1	18.23	9.8	28.84	1.31	30.32	1.25
		2	20.10	9	31.80	1.18		
		3	17.03	9.7	26.94	1.31	28.91	1.18
		4	19.52	8.1	30.88	1.05		
		5	13.73	11.6	21.72	1.62	25.15	1.19
		6	18.06	6.1	28.57	0.76		
		7	17.09	11.4	27.04	1.56	26.67	1.56
		8	16.63	11.3	26.31	1.55		
		9	15.65	9.7	24.76	1.32	26.74	1.49
		10	18.15	12.1	28.71	1.66		
T1 FAILEDPost Rigor WC	Post Rigor WC failed NO OVERNIGHT	1	19.02	9.70	30.09	1.29	27.53	1.25
		2	15.78	9.00	24.96	1.22		
		3	19.17	11.00	30.33	1.49	30.86	1.47
		4	19.84	10.80	31.39	1.45		
		5	16.94	9.70	26.80	1.31	27.95	1.01
		6	18.4	5.80	29.11	0.71		
		7	18.93	10.00	29.95	1.34	27.91	1.45
		8	16.36	11.30	25.88	1.55		
		9	17.62	9.80	27.87	1.32	28.86	1.32
		10	18.86	9.9	29.84	1.32		
T2 Pre Rigor IG	Pre Rigor IG	1	21.71	12.00	34.35	1.61	35.67	1.63
		2	23.39	12.30	37.00	1.65		
		3	19.7	10.60	31.17	1.42	30.99	1.33
		4	19.48	9.40	30.82	1.24		
		5	20.59	11.40	32.57	1.53	30.90	1.59
		6	18.48	12.00	29.24	1.64		
		7	18.48	12.00	29.24	1.64	30.48	1.66
		8	20.05	12.30	31.72	1.67		
		9	23.29	12.80	36.84	1.72	34.41	1.64
		10	20.21	11.60	31.97	1.57		
T3 Pre Rigor IG CO_2	Pre Rigor IG CO_2	1	23.18	12.30	36.67	1.65	35.39	1.57
		2	21.56	11.20	34.11	1.50		
		3	21.36	12.50	33.79	1.69	33.32	1.73
		4	20.76	13.00	32.84	1.77		
		5	21.82	11.10	34.52	1.48	39.27	1.79
		6	27.83	15.6	44.03	2.10		
		7	19.92	10.40	31.51	1.39	31.51	1.39
		8	10.97	7.40				
		9	19.79	11.40	31.31	1.54	40.64	1.72
		10	31.59	14.50	49.98	1.91		
T4 Pre Rigor IB RC	Pre Rigor IB RC	1	38.71	13.20	61.24	1.65	53.08	1.73
		2	28.4	13.70	44.93	1.81		
		3	24.47	10.20	38.71	1.32	48.83	1.71
		4	37.26	16.10	58.95	2.10		
		5	34.99	14.00	55.35	1.80	51.57	1.82
		6	30.2	14.00	47.78	1.84		
		7	28.63	13.00	45.29	1.71	44.41	1.77
		8	27.52	13.80	43.54	1.83		
		9	36.47	14.90			53.57	2.43
		10	33.86	18.10	53.57	2.43		
T5 Pre Rigor IB 1/4 RC	Pre Rigor IB 1/4 RC	1	27.19	13.6	43.01	1.81	36.31	1.70
		2	18.71	11.7	29.60	1.59		
		3	31.55	15.5	49.91	2.06	43.71	2.04
		4	23.71	14.9	37.51	2.03		
		5	31.23	11	49.41	1.38	46.27	1.79
		6	27.27	16.2	43.14	2.20		
		7	29.18	10.9	46.16	1.39	45.54	1.85
		8	28.39	17	44.91	2.31		
		9	25.10	13.3	39.71	1.78	40.21	1.63
		10	25.73	11.3	40.70	1.48		

Table C.15. Temperature control – Replication 3

Temperature and Humidity

Date: Aug / 17 / 2011

Study 1 - Replication 3

Time	Time interval	Post Rigor WC For carcass	Water Temp. ©	Pre Rigor IB For carcass	Chilling room Temp. ©	Chilling room Humidity (%)	Pre Rigor IB 1/4 For carcass	Chilling room Temp. ©
08:41	0	40.00		42.00			36.1	
	5	39.00		39.40			34.5	
	10	38.80		36.50			30.4	
	15	38.40		33.30			26.7	
	20	37.90		30.80			22.8	
	25	37.00		26.90			20	
	30	36.10		24.10			16.8	
	35	35.10		21.70			13.9	
	40	34.10		20.00			11	
	45	33.00		17.10			8.5	
	50	31.90		15.30			6	
	55	30.90		13.80			5	
	60	29.70		11.60			3	
	65	28.70		10.00				
	70	27.70		7.80				
	75	26.60		7.20				
	80	25.80		5.40				
	85	24.80		4.70				
	90	24.00		3.70				
	95	23.00						
	100	22.30						
	105	21.60						
	110	20.80						
	115	20.00						
	120	19.30						
	125	18.70						
	130	18.10						
	135	17.40						
	140	16.70						
	145	16.20						
	150	15.90						
	155	15.20						
	160	14.70						
	165	14.30						
	170	13.80						
	175	13.30						
	180	12.60						
	185	12.40						
	190	11.90						
	195	11.40						
	200	11.00						
	205	10.60						
	210	10.20						
	215	9.60						
	220	9.30						
	225	8.90						
	230	8.50						
	235	8.10						
	240	7.80						
	245	7.50						
	250	7.30						
	255	7.00						
	260	6.80						
	265	6.50						
	270	6.10						
	275	5.90						
	280	5.70						
	285	5.50						
	290	5.30						
	295	5.30						
	300	5.30						
	305	5.10						
	310	4.90						
	315	4.60						
	320	4.50						
	325	4.30						
	330	4.10						
	335	3.70						
	340	3.50						
	345	3.40						
	350	3.20						
	355	3.10						
	360	2.90						
	365	2.80						

Table C.16. Batter and raw meat pH – Replication 3

pH

Date: aug / 23 /2011

Sample Name		batter before overnight			batter after overnight			frozen raw meat before chilling			frozen raw meat after chilling			
		rep 1	rep 2	avg	rep 1	rep 2	*avg*	rep 1	rep 2	avg	rep 1	rep 2	*avg*	avg
Treatment 1 Post Rigor WC	1										5.77	5.76	***5.77***	
	2	5.89	5.88	***5.89***	5.92	5.93	***5.93***				5.78	5.77	***5.78***	5.81
	3										5.88	5.87	***5.88***	
Treatment 2 Pre Rigor IG	1							6.22	6.29					
	2	6.29	6.27	***6.28***	6.12	6.10	***6.11***	6.24	6.28	6.25				
	3							6.27	6.22					
Treatment 3 Pre Rigor IG CO_2	1							6.26	6.29					
	2	6.29	6.29	***6.29***	6.07	6.05	***6.06***	6.18	6.43	6.30				
	3							6.30	6.33					
Treatment 4 Pre Rigor IB RC MON DEC 5	1							6.17	6.23		5.80	5.79	5.80	
	2	6.01	6.01	**6.01**	6.02	6.02	**6.02**	6.33	6.35	6.27	6.05	6.14	6.10	5.98
	3							6.27	6.27		5.98	6.10	6.04	
Treatment 5 Pre Rigor IB 1/4 RC MON DEC 5	1							6.11	6.13		5.83	5.98	5.91	
	2	6.03	6.04	**6.04**	5.78	5.78	**5.78**	6.59	6.58	6.40	6.27	6.36	6.32	6.16
	3							6.48	6.50		6.11	6.41	6.26	

Table C.17. R-value – Replication 3

R-value

Date: aug / 23 / sample 3 g, wave leth, 250 and 260 nm

			frozen muscle before chilling				frozen muscle after chilling			
Sample Name	**sample No.**	**trial No.**	**250 nm**	**260 nm**	**r-value**	**avg**	**250 nm**	**260 nm**	**r-value**	**avg**
blank(ref.)			**0.096**	**0.056**						
Treatment 1 Post Rigor WC	1	1.1	0.4780	0.3430	1.3936	1.3965			1.39626706	1.17610399
		1.2	0.5010	0.3580	1.3994				0.95594093	
	2	2.1	0.4980	0.3010	1.6545	1.5131			0.97373421	0.9903929
		2.2	0.5350	0.3900	1.3718				1.0070516	
	3	3.1	0.5480	0.4260	1.2864	1.2791			0.96062415	0.96062415
		3.2	0.5660	0.4450	1.2719					
Treatment 2 Pre Rigor IG	1	1.1	0.6030	0.6140	0.9821	0.9750				
		1.2	0.6320	0.6530	0.9678					
	2	2.1	0.5980	0.6370	0.9388	0.9405				
		2.2	0.5880	0.6240	0.9423					
	3	3.1	0.5430	0.5690	0.9543	0.9523				
		3.2	0.5740	0.6040	0.9503					
Treatment 3 Pre Rigor IG CO_2	1	1.1	0.6140	0.6350	0.9669	0.9706				
		1.2	0.5690	0.5840	0.9743					
	2	2.1	0.5650	0.5810	0.9725	0.9871				
		2.2	0.5660	0.5650	1.0018					
	3	3.1	0.6190	0.6400	0.9672	0.9635				
		3.2	0.5960	0.6210	0.9597					
Treatment 4 Pre Rigor IB RC	1	1.1	0.3670	0.3940	0.931472081	0.9436	0.3530	0.2910	1.21305842	
		1.2	0.3450	0.3610	0.95567867		0.3350	0.2730	1.22710623	
	2	2.1	0.3730	0.4390	0.849658314	0.8421	0.3560	0.3750	0.94933333	1.0252
		2.2	0.3580	0.4290	0.834498834		0.3500	0.3490	1.00286533	
	3	3.1	0.3570	0.4200	0.85	0.8498	0.3700	0.3780	0.97883598	
		3.2	0.3670	0.4320	0.849537037		0.3480	0.4460	0.78026906	
Treatment 5 Pre Rigor IB 1/4 RC	1	1.1	0.3660	0.3700	0.989189189	0.9946	0.3840	0.3380	1.13609467	
		1.2	0.3640	0.3640	1		0.3800	0.3410	1.1143695	
	2	2.1	0.3390	0.4100	0.826829268	0.7806	0.4060	0.4460	0.9103139	0.9377
		2.2	0.3540	0.4820	0.734439834		0.3900	0.4630	0.84233261	
	3	3.1	0.4060	0.4880	0.831967213	0.8385	0.3870	0.4600	0.84130435	
		3.2	0.4200	0.4970	0.845070423		0.3650	0.4670	0.78158458	

Table C.18. Sarcomere Length – Replication 3

Sarcomere length					Study 1 replication 3				0.6328
Date: aug / 24 /2011		T= from center to the diffraction band							
Sample Name	sample NO	trial No.	D	T			SARCOMERE LENGTH	avg	avg
			mm	mm					
	No.1	No.1-1	100	35.70			1.88		
	No.1	No.1-2	100	40.20			1.70		
	No.1	No.1-3	100	29.40			2.24		
	No.1	No.1-4	100	39.70			1.71		
Post Rigor WC	No.1	No.1-5	100	35.60	36.53		1.89	1.86	
	No.1	No.1-6	100	40.80			1.68		
	No.1	No.1-7	100	34.60			1.94		
	No.1	No.1-8	100	36.30			1.85		
	No.1	No.1-9	100	39.50			1.72		
	No.1	No.1-10	100	33.50			1.99		
	No.2	No. 2-1	100	35.10			1.91		
	No.2	No. 2-2	100	43.40			1.59		
	No.2	No. 2-3	100	34.40			1.95		
	No.2	No. 2-4	100	38.10			1.78		
Post Rigor WC	No.2	No. 2-5	100	41.00	37.16	35.78	1.67	1.83	1.8930
	No.2	No. 2-6	100	36.80			1.83		
	No.2	No. 2-7	100	34.40			1.95		
	No.2	No. 2-8	100	35.50			1.89		
	No.2	No. 2-9	100	38.70			1.75		
	No.2	No. 2-10	100	34.20			1.96		
	No.3	No. 3-1	100	31.20			2.12		
	No.3	No. 3-2	100	33.10			2.01		
	No.3	No. 3-3	100	34.30			1.95		
	No.3	No. 3-4	100	33.20			2.01		
Post Rigor WC	No.3	No. 3-5	100	32.40	33.66		2.05	1.99	
	No.3	No. 3-6	100	34.40			1.95		
	No.3	No. 3-7	100	40.10			1.70		
	No.3	No. 3-8	100	33.10			2.01		
	No.3	No. 3-9	100	31.70			2.09		
	No.3	No. 3-10	100	33.10			2.01		
	No.1	No.1-1	100	63.30			1.18		
	No.1	No.1-2	100	53.10			1.35		
	No.1	No.1-3	100	70.90					
	No.1	No.1-4	100	64.50			1.17		
Pre Rigor IG	No.1	No.1-5	100	61.40	65.21		1.21	1.20	
	No.1	No.1-6	100	65.50			1.15		
	No.1	No.1-7	100	69.50					
	No.1	No.1-8	100	72.70					
	No.1	No.1-9	100	68.70			1.12		
	No.1	No.1-10	100	62.50			1.19		
	No.2	No. 2-1	100	59.70			1.23		
	No.2	No. 2-2	100	59.10			1.24		
	No.2	No. 2-3	100	53.30			1.35		
	No.2	No. 2-4	100	72.60					
Pre Rigor IG	No.2	No. 2-5	100	71.70	60.89	60.52		1.27	1.27222
	No.2	No. 2-6	100	58.10			1.26		
	No.2	No. 2-7	100	60.00			1.23		
	No.2	No. 2-8	100	61.60					
	No.2	No. 2-9	100	53.70			1.34		
	No.2	No. 2-10	100	59.10			1.24		
	No.3	No. 3-1	100	54.60			1.32		
	No.3	No. 3-2	100	51.90			1.37		
	No.3	No. 3-3	100	63.30					
	No.3	No. 3-4	100	55.50			1.30		
Pre Rigor IG	No.3	No. 3-5	100	64.60	55.45			1.35	
	No.3	No. 3-6	100	47.40			1.48		
	No.3	No. 3-7	100	51.20			1.39		
	No.3	No. 3-8	100	52.00			1.37		
	No.3	No. 3-9	100	59.60			1.24		
	No.3	No. 3-10	100	54.40			1.32		

Table C.18. (cont'd)

Pre Rigor IG CO_2	No.1	No.1-1	100	55.40	62.31	59.08	1.31	1.26	1.28158
	No.1	No.1-2	100	74.50					
	No.1	No.1-3	100	60.30			1.23		
	No.1	No.1-4	100	58.60			1.25		
	No.1	No.1-5	100	61.70			1.21		
	No.1	No.1-6	100	74.40					
	No.1	No.1-7	100	66.20					
	No.1	No.1-8	100	54.10			1.33		
	No.1	No.1-9	100	55.50			1.30		
	No.1	No.1-10	100	62.40			1.20		
Pre Rigor IG CO_2	No.2	No. 2-1	100	60.20	57.36		1.23	1.29	
	No.2	No. 2-2	100	51.60			1.38		
	No.2	No. 2-3	100	56.00			1.30		
	No.2	No. 2-4	100	57.70			1.27		
	No.2	No. 2-5	100	63.10					
	No.2	No. 2-6	100	58.30			1.26		
	No.2	No. 2-7	100	55.80			1.30		
	No.2	No. 2-8	100	54.40			1.32		
	No.2	No. 2-9	100	60.50			1.22		
	No.2	No. 2-10	100	56.00			1.30		
Pre Rigor IG CO_2	No.3	No. 3-1	100	59.50	57.58		1.24	1.30	
	No.3	No. 3-2	100	57.40			1.27		
	No.3	No. 3-3	100	66.70					
	No.3	No. 3-4	100	52.30			1.37		
	No.3	No. 3-5	100	55.50			1.30		
	No.3	No. 3-6	100	53.00			1.35		
	No.3	No. 3-7	100	56.90			1.28		
	No.3	No. 3-8	100	54.40			1.32		
	No.3	No. 3-9	100	62.50					
	No.3	No. 3-10	100	57.60			1.27		
T4 Pre Rigor IB RC (FRI DEC 9 2011)	No.1	No.1-1	100	35.80	37.38	37.51	1.88	1.81	1.80618
	No.1	No.1-2	100	38.00			1.78		
	No.1	No.1-3	100	36.20			1.86		
	No.1	No.1-4	100	38.10			1.78		
	No.1	No.1-5	100	39.20			1.73		
	No.1	No.1-6	100	37.40			1.81		
	No.1	No.1-7	100	36.30			1.85		
	No.1	No.1-8	100	40.10			1.70		
	No.1	No.1-9	100	36.20			1.86		
	No.1	No.1-10	100	36.50			1.85		
T4 Pre Rigor IB RC (FRI DEC 9 2011)	No.2	No. 2-1	100	38.30	38.87		1.77	1.75	
	No.2	No. 2-2	100	39.40			1.73		
	No.2	No. 2-3	100	39.60			1.72		
	No.2	No. 2-4	100	40.70			1.68		
	No.2	No. 2-5	100	38.10			1.78		
	No.2	No. 2-6	100	35.80			1.88		
	No.2	No. 2-7	100	41.10			1.66		
	No.2	No. 2-8	100	37.70			1.79		
	No.2	No. 2-9	100	37.20			1.81		
	No.2	No. 2-10	100	40.80			1.68		
T4 Pre Rigor IB RC (FRI DEC 9 2011)	No.3	No. 3-1	100	37.10	36.29		1.82	1.86	
	No.3	No. 3-2	100	38.20			1.77		
	No.3	No. 3-3	100	35.80			1.88		
	No.3	No. 3-4	100	38.80			1.75		
	No.3	No. 3-5	100	36.50			1.85		
	No.3	No. 3-6	100	38.00			1.78		
	No.3	No. 3-7	100	35.60			1.89		
	No.3	No. 3-8	100	36.20			1.86		
	No.3	No. 3-9	100	34.00			1.97		
	No.3	No. 3-10	100	32.70			2.04		
T5 Pre Rigor IB 1/4 RC (FRI DEC 9 2011)	No.1	No.1-1	100	35.40	36.24	36.68	1.90	1.86	1.8462
	No.1	No.1-2	100	39.60			1.72		
	No.1	No.1-3	100	34.20			1.96		
	No.1	No.1-4	100	33.00			2.02		
	No.1	No.1-5	100	38.20			1.77		
	No.1	No.1-6	100	37.10			1.82		
	No.1	No.1-7	100	34.10			1.96		
	No.1	No.1-8	100	38.10			1.78		
	No.1	No.1-9	100	37.00			1.82		
	No.1	No.1-10	100	35.70			1.88		
T5 Pre Rigor IB 1/4 RC (FRI DEC 9 2011)	No.2	No. 2-1	100	43.00	35.76		1.60	1.89	
	No.2	No. 2-2	100	36.10			1.86		
	No.2	No. 2-3	100	32.50			2.05		
	No.2	No. 2-4	100	31.00			2.14		
	No.2	No. 2-5	100	37.30			1.81		
	No.2	No. 2-6	100	38.50			1.76		
	No.2	No. 2-7	100	35.00			1.92		
	No.2	No. 2-8	100	36.60			1.84		
	No.2	No. 2-9	100	35.40			1.90		
	No.2	No. 2-10	100	32.20			2.06		
T5 Pre Rigor IB 1/4 RC (FRI DEC 9 2011)	No.3	No. 3-1	100	38.00	38.04		1.78	1.78	
	No.3	No. 3-2	100	35.70			1.88		
	No.3	No. 3-3	100	40.40			1.69		
	No.3	No. 3-4	100	39.10			1.74		
	No.3	No. 3-5	100	37.40			1.81		
	No.3	No. 3-6	100	37.40			1.81		
	No.3	No. 3-7	100	39.20			1.73		
	No.3	No. 3-8	100	36.50			1.85		
	No.3	No. 3-9	100	39.30			1.73		
	No.3	No. 3-10	100	37.40			1.81		

Table C.19. Fragmentation index – Replication 3

GFI Date: aug / 25 / 2011					1000		
sample name	No.	Wt dried screen	Wt wet sample	Wt dried sample + screen	wt dried sample	GFI	avg
Treatment 1 Post rigor WC	1.1	0.7137	4.96	1.5772	0.8635	174.0927	176.5544
	1.2	0.7144	4.8	1.4644	0.7500	156.2500	
	2.1	0.7134	4.97	1.6758	0.9624	193.6419	
	2.2	0.7204	4.95	1.6607	0.9403	189.9596	
	3.1	0.7067	4.9	1.475	0.7683	156.7959	
	3.2	0.7064	4.81	1.6135	0.9071	188.5863	
Treatment 2 Pre rigor IG	1.1	0.7063	4.73	1.6848	0.9785	206.8710	200.5802
	1.2	0.7057	4.83	1.6911	0.9854	204.0166	
	2.1	0.7083	4.71	1.6021	0.8938	189.7665	
	2.2	0.7132	4.77	1.6412	0.9280	194.5493	
	3.1	0.7094	4.87	1.7066	0.9972	204.7639	
	3.2	0.7141	4.98	1.7276	1.0135	203.5141	
Treatment 3 Pre rigor IG CO_2	1.1	0.7106	4.77	1.7643	1.0537	220.9015	202.8498
	1.2	0.703	4.7	1.6739	0.9709	206.5745	
	2.1	0.7007	4.9	1.6791	0.9784	199.6735	
	2.2	0.7066	4.76	1.7168	1.0102	212.2269	
	3.1	0.7085	4.64	1.6242	0.9157	197.3491	
	3.2	0.7007	4.82	1.5701	0.8694	180.3734	
Treatment 4 Pre rigor IB RC	1.1	0.6708	4.67	1.6031	0.9323	199.6360	204.9111
	1.2	0.6741	4.90	1.7017	1.0276	209.7143	
	2.1	0.6873	4.95	1.728	1.0407	210.2424	
	2.2	0.6823	5.00	1.695	1.0127	202.5400	
	3.1	0.7199	5.00	1.6785	0.9586	191.7200	
	3.2	0.7219	4.97	1.7935	1.0716	215.6137	
Treatment 5 Pre Rigor IB RC 1/4	1.1	0.7309	4.92	1.6986	0.9677	196.6870	215.1066
	1.2	0.7342	4.94	1.7514	1.0172	205.9109	
	2.1	0.7074	5.00	1.854	1.1466	229.3200	
	2.2	0.7163	4.90	1.7934	1.0771	219.8163	
	3.1	0.7211	4.96	1.7845	1.0634	214.3952	
	3.2	0.7301	4.90	1.8302	1.1001	224.5102	

Table C.20. Cooking yield – Replication 3

Cooking Yield (Breast for shear force) Study 1 Replication 3 Date: Aug 18 / 2011								
Sample Name	No.	tube no.	wt tube before stuffing	wt tube + batter before cooking	wt empty tube after cooking	wt gel after cooking	Cooking yield (%)	Average
			g	g	g	g		
T1 Post Rigor WC	1	1	183.52	236.65	184.97	45.73	88.80%	88.50%
	2	2	183.25	236.33	185.88	46.51	92.58%	
	3	3	182.86	240.05	185.93	50.46	93.60%	
	4	4	180.03	233.92	180.88	44.52	84.19%	
	5	5	179.63	233.92	180.27	44.60	83.33%	
T1 FAILED Post Rigor WC	1	1	179.73	234.53	180.71	44.87	83.67%	84.27%
	2	2	180.30	235.01	181.33	44.89	83.93%	
	3	3	180.56	234.98	181.45	45.12	84.55%	
	4	4	180.13	234.89	181.47	45.16	84.92%	
	5		179.50	234.68	180.75	44.90	83.64%	
T2 Pre Rigor IG	1	5	183.22	237.62	184.63	47.20	89.36%	91.91%
	2	6	182.75	237.00	184.35	49.18	93.60%	
	3	7	183.78	237.31	184.80	47.81	91.22%	
	4	8	182.73	237.84	183.54	50.70	93.47%	
	5		183.80	237.58	185.42	48.07	92.39%	
T3 Pre Rigor IG CO_2	1	9	183.95	238.12	185.34	46.61	88.61%	89.51%
	2	10	183.62	238.05	185.01	47.95	90.65%	
	3	11	183.52	238.11	185.49	48.16	91.83%	
	4	12	182.84	237.54	184.26	46.14	86.95%	
	5		184.33	241.71	185.65	49.02	87.73%	
T4 Pre Rigor IB RC	1	13	184.04	238.81	185.00	48.81	90.87%	89.88%
	2	14	182.86	237.23	184.00	47.99	90.36%	
	3	15	183.28	234.80	184.04	46.68	92.08%	
	4	16	179.92	234.87	181.04	46.25	86.21%	
	5		179.78	237.69	180.54	46.46		
T5 Pre Rigor IB 1/4 RC	1	17	183.31	237.55	184.17	49.23	92.35%	90.34%
	2	18	183.02	237.21	184.17	49.31	93.12%	
	3	19	182.83	237.26	183.78	47.48	88.98%	
	4	20	179.87	235.26	180.87	47.14	86.91%	
	5		180.09	235.17	180.67	46.75	85.93%	

Table C.21. Fragmentation Index – Replication 3

Torsion Test Study 1 Replication 2

Date: july / 14-15 / 2011

Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
Post Rigor WC	1	23.87	8.8	37.76	1.12	35.41	1.13
	2	20.89	8.8	33.05	1.14		
	3	17.32	8.2	27.40	1.08	30.15	1.17
	4	20.79	9.6	32.89	1.26		
	5	21.21	7.5	33.55	0.94	36.52	0.97
	6	24.96	8	39.49	0.99		
	7	15.51	7.6	24.54	1.01	27.92	1.01
	8	19.79	7.9	31.31	1.02		
	9	19.96	8	31.58	1.03	31.65	0.97
	10	20.05	7.2	31.72	0.91		
Post Rigor WC failed NO OVERNIGHT	1	31.4	10.50	49.67	1.31	48.47	1.46
	2	29.88	12.40	47.27	1.61		
	3	29.13	9.30	46.08	1.15	47.03	1.33
	4	30.33	11.80	47.98	1.51		
	5	29.47	11.20	46.62	1.43	52.34	1.32
	6	36.7	10.10	58.06	1.20		
	7	29.67	10.10	46.94	1.26	46.04	1.18
	8	28.54	9.00	45.15	1.11		
	9			0.00	0.00	0.00	0.00
	10			0.00	0.00		
Pre Rigor IG	1	40.66	13.50	64.32	1.68	65.62	1.78
	2	42.3	14.90	66.92	1.87		
	3	47.45	14.90	75.07	1.83	74.88	1.79
	4	47.21	14.40	74.69	1.76		
	5	55.62	17.30	87.99	2.12	77.39	2.04
	6	42.22	15.50	66.79	1.97		
	7	51.09	16.80	80.82	2.08	77.57	1.72
	8	46.98	11.70	74.32	1.36		
	9	41.79	14.10	66.11	1.76	73.51	1.82
	10	51.14	15.50	80.90	1.89		
Pre Rigor IG CO_2	1	34.73	13.40	54.94	1.71	52.61	1.55
	2	31.78	11.00	50.28	1.38		
	3	26.44	11.40	41.83	1.48	51.22	1.42
	4	38.31	11.20	60.61	1.35		
	5	39.45	12.30	62.41	1.51	60.81	1.56
	6	37.43	12.9	59.21	1.62		
	7	44.48	12.70	70.37	1.53	60.12	1.38
	8	31.52	10.00	49.86	1.23		
	9	33.17	13.20	52.47	1.70	52.82	1.55
	10	33.6	11.20	53.16	1.39		
Pre Rigor IB RC	1	31.8	11.70	50.31	1.48	51.88	1.57
	2	33.79	12.90	53.46	1.65		
	3	36.35	11.00	57.51	1.34	58.85	1.32
	4	38.05	10.80	60.20	1.30		
	5	22.68	5.40	35.88	0.62	35.83	0.99
	6	22.62	10.40	35.78	1.37		
	7	35.07	10.90	55.48	1.34	55.34	1.28
	8	34.89	10.10	55.20	1.22		
	9	35.7	11.80	56.48	1.47	57.15	1.48
	10	36.55	12.00	57.82	1.49		
Pre Rigor IB 1/4 RC	1	36.24	12.5	57.33	1.57	51.51	1.41
	2	28.88	10	45.69	1.25		
	3	38.71	11.8	61.24	1.44	59.55	1.40
	4	36.58	11.1	57.87	1.35		
	5	29.00	12.1	45.88	1.57	50.89	1.56
	6	35.34	12.4	55.91	1.56		
	7	35.12	11.3	55.56	1.40	54.77	1.29
	8	34.12	9.8	53.98	1.18		
	9	36.48	10.4	57.71	1.25	62.84	1.24
	10	42.96	10.6	67.96	1.22		

APPENDIX D

RAW DATA STUDY 2

Table D.1. Batter temperature monitoring – Replication 1

Study 2 replication 1

	Sample Name	Temperature ºC
T1 Regular Salt	T1RS MIN 6	13.5
	T1RS MIN 9	20
	T1RS MIN 12	24.5
	T1RS MIN 15	26.5
	T1RS MIN 18	28.6
	T1RS MIN 21	30
	T1RS MIN 24	28.2
	T1RS MIN 27	

	Sample Name	Temperature ºC
T5 Regular Salt	T1RS MIN 6	-2.4
	T1RS MIN 9	5.1
	T1RS MIN 12	13.12
	T1RS MIN 15	18.9
	T1RS MIN 18	20.3
	T1RS MIN 21	22.7
	T1RS MIN 24	23.7
	T1RS MIN 27	27.4

	Sample Name	Temperature ºC
T1 Low Salt	T1RS MIN 6	15.2
	T1RS MIN 9	21.4
	T1RS MIN 12	25.5
	T1RS MIN 15	28.4
	T1RS MIN 18	30.4
	T1RS MIN 21	31.7
	T1RS MIN 24	32.6
	T1RS MIN 27	

	Sample Name	Temperature ºC
T5 Low Salt (lost sample)	T1RS MIN 6	-
	T1RS MIN 9	-
	T1RS MIN 12	-
	T1RS MIN 15	-
	T1RS MIN 18	-
	T1RS MIN 21	-
	T1RS MIN 24	-
	T1RS MIN 27	-

Table D.2. pH before and after chilling – Replication 1

Study 2 Replication 1 Raw meat pH		
TREATMETNT	Before chilling	After Chiling
T1	5.78	5.62
T1'	6.01	5.62
T5	5.79	5.63
T5'	6.15	5.77

Table D.3. R-value before and after chilling – Replication 1

R-value													
Study 2 Replication 1	sample 3 g, wave leth, 250 and 260 nm												
Frozen muscle BEFORE CHILLING							Frozen muscle AFTER CHILLING						
Sample Name	sample No.	trial No.	250 nm	260 nm	r-value	average	sample No.	trial No.	250 nm	260 nm	r-value	average
blank(ref.)												
T1 REG NA	1	1.1	0.1720	0.1400	1.2286	1.3857	1	1.1	0.1470	0.1060	1.3868	1.3539
		1.2	0.1690	0.1330	1.2707			1.2	0.1440	0.1090	1.3211	
	2	2.1	0.1790	0.1300	1.3769		2	2.1	0.1580	0.1090	1.4495	1.3646
		2.2	0.1800	0.1250	1.4400			2.2	0.1510	0.1180	1.2797	
	3	3.1	0.1900	0.1240	1.5323		3	3.1	0.1940	0.1300	1.4923	1.4033
		3.2	0.1700	0.1160	1.4655			3.2	0.1840	0.1400	1.3143	
T1 LOW NA	1	1.1	0.1660	0.1250	1.3280	1.2135	1	1.1	0.3210	0.2430	1.3210	1.1373
		1.2	0.1570	0.1200	1.3083			1.2	0.1850	0.1940	0.9536	
	2	2.1	0.1730	0.1380	1.2536		2	2.1	0.1560	0.1220	1.2787	1.2853
		2.2	0.1800	0.1680	1.0714			2.2	0.3010	0.2330	1.2918	
	3	3.1	0.1660	0.1440	1.1528		3	3.1	0.1340	0.0980	1.3673	1.2661
		3.2	0.1680	0.1440	1.1667			3.2	0.1130	0.0970	1.1649	
T5 REG NA	1	1.1	0.3100	0.2250	1.3778	1.3907	1	1.1	0.3410	0.2460	1.3862	1.4002
		1.2	0.3120	0.2510	1.2430			1.2	0.3380	0.2390	1.4142	
	2	2.1	0.3370	0.2230	1.5112		2	2.1	0.3320	0.2310	1.4372	1.4279
		2.2	0.3350	0.2350	1.4255			2.2	0.3050	0.2150	1.4186	
	3	3.1	0.3170	0.2300	1.3783		3	3.1	0.3620	0.2600	1.3923	1.3908
		3.2	0.3380	0.2400	1.4083			3.2	0.3390	0.2440	1.3893	
T5 LOW NA	1	1.1	0.3270	0.3470	0.9424	0.9588	1	1.1	0.3290	0.2710	1.2140	1.2143
		1.2	0.3380	0.3570	0.9468			1.2	0.3000	0.2470	1.2146	
	2	2.1	0.3530	0.3360	1.0506		2	2.1	0.3180	0.3310	0.9607	0.9757
		2.2	0.3520	0.3400	1.0353			2.2	0.3170	0.3200	0.9906	
	3	3.1	0.3550	0.3980	0.8920		3	3.1	0.3670	0.3230	1.1362	1.1503
		3.2	0.3560	0.4020	0.8856			3.2	0.3470	0.2980	1.1644	

Table D.4. Batter pH – Replication 1

Study 2 Replication 1

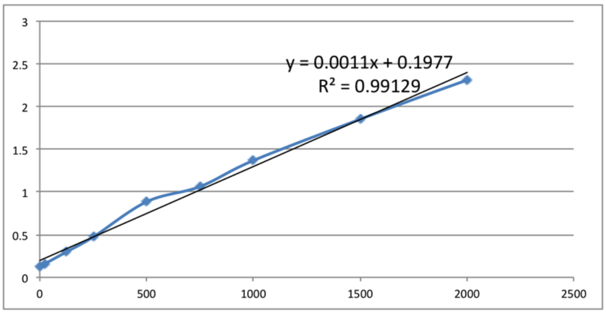
batter pH

	T1 CB-T 2% salt		T1´ CB-T 1% salt		T5 HB-1/4 CFAC 2% salt		T5' HB-1/4 CFAC 1% salt	
min of mincing	NO	OVN	NO	OVN	NO	OVN	NO	OVN
6	5.74	5.88	5.75	5.82	5.9	6.04	0	0
9	5.775	5.875	5.745	5.815	5.845	5.89	0	0
12	5.805	5.89	5.77	5.81	5.835	5.79	0	0
15	5.83	5.86	5.77	5.81	5.75	5.77	0	0
18	5.82	5.875	5.77	5.81	5.755	5.77	0	0
21	5.83	5.87	5.78	5.81	5.725	5.775	0	0
24	5.83	5.87	5.78	5.81	5.75	5.785	0	0
27	-	-	-	-	5.76	5.78	0	0

Table D.5. Protein Solubility, CB-T 2% – Replication 1

Study 2 replication 1
8/14/12 T1 reg soidum

[Protein] ug/m	absorbance 1	absorbance 2	average
2000	2.343	2.291	2.317
1500	1.854	1.852	1.853
1000	1.385	1.353	1.369
750	1.053	1.074	1.0635
500	0.881	0.89	0.8855
250	0.472	0.473	0.4725
125	0.299	0.298	0.2985
25	0.161	0.161	0.161
0	0.132	0.133	0.1325



	CBT- 2%				initial [Protein] g/gbatter	0.046651538	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	% prot sol
14	min6	1.274	1.277	1.2755	979.82	0.039	84.01%
20	min 9	1.278	1.284	1.281	984.82	0.039	84.44%
25	min 12	1.324	1.337	1.3305	1029.82	0.041	88.30%
27	min 15	1.426	1.579	1.5025	1186.18	0.047	101.71%
28	min 18	1.305	1.321	1.313	1013.91	0.041	86.93%
29	min 21	1.333	1.343	1.338	1036.64	0.041	88.88%
30	min 24	1.333	1.35	1.3415	1039.82	0.042	89.16%

40 dilution factor
1000000 micrograms to grams

Table D.6. Protein Solubility, CB-T 1% – Replication 1

Study 2 Replication 1
CB-T 1%

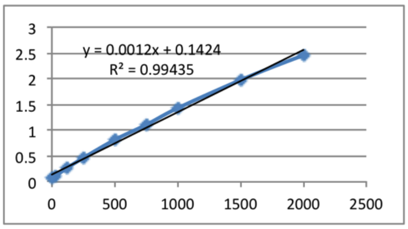
[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.392	2.392	2.392
1500	1.884	1.884	1.884
1000	1.386	1.386	1.386
750	1.085	1.085	1.085
500	0.799	0.799	0.799
250	0.466	0.466	0.466
125	0.297	0.297	0.297
25	0.145	0.145	0.145
0	0.113	0.113	0.113

					initial [Protein] ug/	0.047	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	% prot sol
15	min6	1.358	1.324	1.341	1065.45	0.043	91.35%
21	min 9	1.334	1.333	1.3335	1058.64	0.042	90.77%
26	min 12	1.378	1.453	1.4155	1133.18	0.045	97.16%
28	min 15	1.347	1.367	1.357	1080.00	0.043	92.60%
30	min 18	1.351	1.37	1.3605	1083.18	0.043	92.87%
32	min 21	1.411	1.42	1.4155	1133.18	0.045	97.16%
33	min 24	1.348	1.381	1.3645	1086.82	0.043	93.19%

Table D.7. Protein Solubility, HB- ¼ CFAC 2% – Replication 1

HB- 1/4 CFAC 2%

[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.423	2.512	2.4675
1500	2.013	1.936	1.9745
1000	1.456	1.403	1.4295
750	1.132	1.082	1.107
500	0.804	0.827	0.8155
250	0.459	0.47	0.4645
125	0.275	0.276	0.2755
25	0.108	0.108	0.108
0	0.074	0.074	0.074



1.119 1.5 1.3095

	HB- 1/4 CFAC 2%				initial [Protein] ug/ml	0.047	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	% prot sol
-2.5	min6	1.119	1.15	1.1345	826.75	0.033	70.89%
5	min 9	1.168	1.171	1.1695	855.92	0.034	73.39%
13	min 12	1.2	1.138	1.169	855.50	0.034	73.35%
19	min 15	1.156	1.286	1.221	898.83	0.036	77.07%
20	min 18	1.168	1.265	1.2165	895.08	0.036	76.75%
23	min 21	1.349	1.257	1.303	967.17	0.039	82.93%
24	min 24	1.248	1.21	1.229	905.50	0.036	77.64%
27	min 27	1.184	1.165	1.1745	860.08	0.034	73.75%

Table D.8. Torsion test, CB-T 2% – Replication 1

Torsion Test

Study 2 replication 1

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC REG SODIUM	T1RS MIN 6	1	13.35	9.2	21.12	1.27	19.96	1.17
		2	12.39	9.3	19.60	1.29		
		3	11.67	11	18.46	1.55		
		4	16.47	9.2	26.06	1.24		
		5	12.03	5.6	19.03	0.74		
		6	9.8	6.7	15.50	0.92		
		7						
		8						
		9						
		10						
	T1RS MIN 9	1	19.78	11.40	31.29	1.54	16.89	1.29
		2	9.15	10.60	14.48	1.51		
		3	8.65	7.70	13.68	1.08		
		4	8.1	11.60	12.81	1.67		
		5	9.77	7.00	15.46	0.97		
		6	7.78	6.70	12.31	0.94		
		7	11.52	9.60	18.22	1.34		
		8						
		9						
		10						
	T1RS MIN 12	1	12.08	7.90	19.11	1.08	18.19	1.11
		2	12.02	8.20	19.02	1.13		
		3	11.05	7.80	17.48	1.08		
		4	11.05	7.80	17.48	1.08		
		5	12.98	9.20	20.53	1.27		
		6	10.26	8.00	16.23	1.11		
		7	12.71	8.90	20.11	1.23		
		8	11.52	7.50	18.22	1.03		
		9	10.42	7.10	16.48	0.98		
		10	10.88	8.10	17.21	1.12		
	T1RS MIN 15	1	13.5	8.50	21.36	1.16	19.05	1.13
		2	11.89	8.00	18.81	1.10		
		3	11.91	7.90	18.84	1.08		
		4	10.69	7.90	16.91	1.09		
		5	11.08	8.30	17.53	1.15		
		6	13.51	8.7	21.37	1.19		
		7	12.05	8.40	19.06	1.16		
		8	12.23	8.30	19.35	1.14		
		9	11.5	7.90	18.19	1.09		
		10						
	T1RS MIN 18	1	24.45	9.20	38.68	1.17	27.52	1.28
		2	13.01	9.50	20.58	1.31		
		3	14.2	9.80	22.46	1.35		
		4	12.14	9.10	19.21	1.26		
		5	16.83	9.70	26.63	1.31		
		6	13.39	9.20	21.18	1.27		
		7	22.87	9.50	36.18	1.23		
		8	22.26	10.20	35.22	1.34		
		9						
		10						
	T1RS MIN 21	1	11.09	8.3	17.54	1.15	19.65	1.20
		2	12.48	8.5	19.74	1.17		
		3	10.77	9.1	17.04	1.27		
		4	12.88	8.6	20.38	1.18		
		5	13.79	9.1	21.82	1.25		
		6	12.5	8.5	19.78	1.17		
		7	13.76	9.1	21.77	1.25		
		8	12.08	8.3	19.11	1.14		
		9						
		10						
	T1RS MIN 24	1	12.94	8.6	20.47	1.18	19.69	1.30
		2	10.53	9.4	16.66	1.32		
		3	14.01	9.5	22.16	1.30		
		4	12.54	8.5	19.84	1.17		
		5	13.27	12.6	20.99	1.78		
		6	11.8	8.3	18.67	1.14		
		7	11.11	9.1	17.58	1.27		
		8	13.38	9.2	21.17	1.27		
		9						
		10						
	T1RS MIN 27	1					#¡DIV/0!	#¡DIV/0!
		2						
		3						
		4						
		5						
		6						
		7						
		8						
		9						
		10						

Table D.9. Torsion test, CB-T 1% – Replication 1

Torsion Test

Study 2 replication 1

	Sample Name	Sample #	Torque (%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC LOW SODIUM	T1LS MIN 6	1	7.61	6	12.04	0.83	11.26	0.91
		2	9.10	8	14.40	1.12		
		3	6.49	5	10.27	0.69		
		4	7.18	5.6	11.36	0.78		
		5	7.55	5.2	11.94	0.72		
		6	4.77	9	7.55	1.31		
		7						
		8						
		9						
		10						
	T1LS MIN 9	1	8.75	8.50	13.84	1.20	16.15	0.98
		2	10.02	6.80	15.85	0.93		
		3	8.86	5.90	14.02	0.81		
		4	8.53	6.30	13.49	0.87		
		5	10.21	7.50	16.15	1.04		
		6	9.79	6.90	15.49	0.95		
		7	11.37	8.00	17.99	1.10		
		8	10.89	6.90	17.23	0.94		
		9	13.43	7.40	21.25	1.00		
		10						
	T1LS MIN 12	1	10.99	10.40	17.39	1.47	16.52	1.04
		2	9.88	7.30	15.63	1.01		
		3	10.5	7.50	16.61	1.03		
		4	14.61	8.50	23.11	1.15		
		5	9.36	5.80	14.81	0.79		
		6	9.29	7.40	14.70	1.03		
		7	9.27	7.00	14.67	0.97		
		8	9.14	7.00	14.46	0.97		
		9	10.92	6.90	17.28	0.94		
		10						
	T1LS MIN 15	1	11.38	7.7	18.00	1.06	17.95	1.07
		2	11.07	7.60	17.51	1.05		
		3	11.41	7.90	18.05	1.09		
		4	9.67	7.00	15.30	0.97		
		5	13.25	8.10	20.96	1.10		
		6	10.44	7.2	16.52	0.99		
		7	11.32	8.70	17.91	1.21		
		8	12.24	8.20	19.36	1.13		
		9						
		10						
	T1LS MIN 18	1	12.52	8.00	19.81	1.09	16.32	1.06
		2	9.61	7.20	15.20	1.00		
		3	10.7	8.20	16.93	1.14		
		4	9.25	7.50	14.63	1.05		
		5	8.83	7.10	13.97	0.99		
		6	10.59	8.30	16.75	1.15		
		7	11.43	7.20	18.08	0.98		
		8	9.76	7.80	15.44	1.09		
		9	10.17	7.90	16.09	1.10		
		10						
	T1LS MIN 21	1	10.33	7.5	16.34	1.04	18.77	1.08
		2	10.86	7.6	17.18	1.05		
		3	10.86	7.6	17.18	1.05		
		4	11.63	7.8	18.40	1.07		
		5	12.39	8	19.60	1.09		
		6	13.82	8.7	21.86	1.19		
		7	12.39	8	19.60	1.09		
		8	11.05	8.4	17.48	1.17		
		9	13.48	7.5	21.33	1.01		
		10						
	T1LS MIN 24	1	11.21	7.7	17.73	1.06	18.18	1.11
		2	11.21	7.7	17.73	1.06		
		3	12.36	8.2	19.55	1.12		
		4	10.95	8.8	17.32	1.23		
		5	10.19	7.6	16.12	1.05		
		6	10.76	8	17.02	1.11		
		7	13.77	8.3	21.78	1.13		
		8						
		9						
		10						
	T1LS MIN 27						#¡DIV/0!	#¡DIV/0!

Table D.10. Torsion test, HB- ¼CFAC 2% – Replication 1

Torsion Test

Study 2 replication 1

	Sample Name	Sample #	Torque (%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T5 PRE Rigor 1/4 CFC REG SODIUM	T5RS MIN 6	1	15.48	8.2	24.49	1.10	36.34	0.97
		2	15.47	7.3	24.47	0.96		
		3	28.5	8.3	45.09	1.00		
		4	22.95	7.2	36.31	0.88		
		5	27.65	8.7	43.74	1.07		
		6	21.88	7	34.61	0.86		
		7	25.96	7.8	41.07	0.95		
		8	25.88	7.8	40.94	0.95		
		9						
		10						
	T5RS MIN 9	1	27.24	8.30	43.09	1.01	43.08	1.03
		2	29.12	9.20	46.07	1.13		
		3	24.9	8.10	39.39	1.00		
		4	30.41	9.10	48.11	1.11		
		5	24.25	7.40	38.36	0.90		
		6	28.74	8.70	45.47	1.06		
		7	25.94	7.90	41.04	0.96		
		8						
		9						
		10						
	T5RS MIN 12	1	27.91	7.40	44.15	0.87	42.61	1.03
		2	28.49	8.30	45.07	1.00		
		3	25.47	7.90	40.29	0.97		
		4	22.9	8.20	36.23	1.03		
		5	30.4	9.60	48.09	1.18		
		6	26.43	8.80	41.81	1.09		
		7						
		8						
		9						
		10						
	T5RS MIN 15	1	24.95	8.10	39.47	1.00	46.86	1.13
		2	38.52	10.10	60.94	1.19		
		3	29.25	8.10	46.27	0.97		
		4	29.44	10.70	46.57	1.35		
		5	25.49	9.00	40.33	1.13		
		6	31.55	9.3	49.91	1.13		
		7	27.57	8.70	43.62	1.07		
		8	29.03	9.60	45.93	1.19		
		9	30.76	9.50	48.66	1.16		
		10						
	T5RS MIN 18	1	25.07	8.50	39.66	1.06	41.35	1.04
		2	22.87	8.30	36.18	1.05		
		3	26.88	8.30	42.52	1.02		
		4	28.52	8.30	45.12	1.00		
		5	25.97	8.10	41.08	0.99		
		6	26.69	8.30	42.22	1.02		
		7	26.98	9.20	42.68	1.15		
		8						
		9						
		10						
	T5RS MIN 21	1	25.52	9	40.37	1.13	44.26	1.15
		2	27.23	8.5	43.08	1.04		
		3	29.5	9.4	46.67	1.16		
		4	25.65	8.6	40.58	1.07		
		5	27.76	9.7	43.92	1.22		
		6	32.09	10	50.77	1.23		
		7	29.65	9.5	46.91	1.17		
		8	26.44	9.1	41.83	1.14		
		9						
		10						
	T5RS MIN 24	1	22.21	7.1	35.14	0.88	37.05	1.00
		2	24.47	7.5	38.71	0.92		
		3	21.7	8	34.33	1.02		
		4	24.75	8	39.15	0.99		
		5	22.3	8.2	35.28	1.04		
		6	24.38	8.4	38.57	1.05		
		7	24.12	8.6	38.16	1.08		
		8						
		9						
		10						
	T5RS MIN 27	1	24.43	9.1	38.65	1.16	35.08	1.05
		2	22.4	7.8	35.44	0.98		
		3	21.2	8	33.54	1.02		
		4	21.17	7.8	33.49	0.99		
		5	23.04	8.9	36.45	1.14		
		6	22.93	9	36.28	1.15		
		7	22.53	8.1	35.64	1.02		
		8	19.72	7.6	31.20	0.97		
		9						
		10						

Table D.11. Batter temperature monitoring – Replication 2

Study 2 replication 2
Batter temperature

T1 Regular Salt

Sample Name	real time	mixing time	Temperature ºC	rpm	notes
time 0			7.6		
T1RS MIN 6		6	19	4000	72-81
T1RS MIN 9		9	22.5	4000	72-81
T1RS MIN 12		12	26.5	4000	72-81
T1RS MIN 15		15	29.2	4000	72-81
T1RS MIN 18		18	30.7	4000	72-81
T1RS MIN 21		21	31.9	4000	72-81
T1RS MIN 24		24	32.7	4000	72-81
T1RS MIN 27		27	33.3	4000	72-81

T5 Regular Salt

Sample Name	real time	mixing time	Temperature ºC	rpm	notes
time 0			-0.1		
T1RS MIN 6		6	-1.9	4000	72-81
T1RS MIN 9		9	1.3	4000	72-81
T1RS MIN 12		12	10.5	4000	72-81
T1RS MIN 15		15	17.2	4000	72-81
T1RS MIN 18		18	21.4	4000	72-81
T1RS MIN 21		21	24.5	4000	72-81
T1RS MIN 24		24	26.75	4000	72-81
T1RS MIN 27		27	28.4	4000	72-81

T1 Low Salt

Sample Name	real time	mixing time	Temperature ºC	rpm	notes
time 0			6.7		
T1RS MIN 6		6	20.3	4000	72-81
T1RS MIN 9		9	25.7	4000	72-81
T1RS MIN 12		12	29.2	4000	72-81
T1RS MIN 15		15	31.2	4000	72-81
T1RS MIN 18		18	32.5	4000	72-81
T1RS MIN 21		21	32.8	4000	72-81
T1RS MIN 24					
T1RS MIN 27					

T5 Low Salt

Sample Name	real time	mixing time	Temperature ºC	rpm	notes
time 0			0.4		
T1RS MIN 6		6	-1.25	4000	72-81
T1RS MIN 9		9	7.4	4000	72-81
T1RS MIN 12		12	15.4	4000	72-81
T1RS MIN 15		15	20.75	4000	72-81
T1RS MIN 18		18	24.4	4000	72-81
T1RS MIN 21		21	26.55	4000	72-81
T1RS MIN 24		24	28.2	4000	72-81
T1RS MIN 27		27	29.2	4000	72-81

Table D.12. pH raw meat before and after chilling – Replication 2

pH									
Study 2 REPLICATION 2									
Sample Name	**before chilling frozen raw meat**					**after chilling frozen raw meat**			
		rep 1	**rep 2**	***avg***	***avg***	**rep 1**	**rep 2**	***avg***	***avg***
T1 REG NA	1	6.08	6.02	***6.05***	***6.10***	5.72	5.71	***5.72***	***5.66***
	2	6.11	6.15	***6.13***		5.69	5.69	***5.69***	
	3	6.19	6.27	***6.23***		5.73	5.71	***5.72***	
	4	6.1	6.09	***6.10***		5.63	5.61	***5.62***	
	5	5.98	6	***5.99***		5.64	5.46	***5.55***	
T1' LOW NA	1	6.10	6.07	***6.09***	***6.16***	5.74	5.73	***5.74***	***5.79***
	2	6.22	6.21	***6.22***		5.76	5.81	***5.79***	
	3	5.98	6.02	***6.00***		5.88	5.84	***5.86***	
	4	6.21	6.23	***6.22***		5.8	5.78	***5.79***	
	5	6.29	6.3	***6.30***					
T5 REG NA	1	5.88	5.87	***5.88***	***6.00***	5.75	5.75	***5.75***	***5.63***
	2	5.98	6.01	***6.00***		5.89	5.84	***5.87***	
	3	6.03	5.98	***6.01***		5.20	5.34	***5.27***	
T5 LOW NA	1	6	5.83	***5.92***	***6.12***	5.79	5.83	***5.81***	***5.93***
	2	6.13	6.14	***6.14***		6	5.98	***5.99***	
	3	6.3	6.34	***6.32***		5.96	5.99	***5.98***	

Table D.13. Raw meat R-value before and after chilling – Replication 2

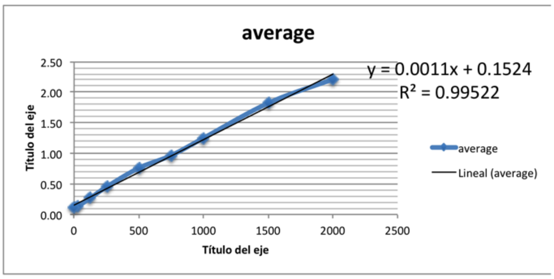
Study 2 REPLICATION 2												
R-value												
	sample 3 g, wave leth, 250 and 260 nm											
Frozen muscle BEFORE CHILLING							**Frozen muscle AFTER CHILLING**					
Sample Name	**sample No.**	**trial No.**	**250 nm**	**260 nm**	**r-value**	**average**	**sample No.**	**trial No.**	**250 nm**	**260 nm**	**r-value**	**average**
blank(ref.)												
T1 REG NA	1	1.1	0.366	0.332	1.1024	1.0757	1	1.1	0.3870	0.2820	1.3723	1.3431
		1.2	0.4110	0.3590	1.1448			1.2	0.3810	0.2900	1.3138	
	2	2.1	0.3690	0.3450	1.0696		2	2.1	0.3680	0.2650	1.3887	1.3890
		2.2	0.3340	0.3150	1.0603			2.2	0.3390	0.2440	1.3893	
	3	3.1	0.3470	0.3470	1.0000		3	3.1	0.3140	0.2300	1.3652	1.3704
		3.2	0.3360	0.3300	1.0182			3.2	0.3370	0.2450	1.3755	
	4	4.1	0.3670	0.3450	1.0638		4	4.1	0.2950	0.2130	1.3850	1.3895
		4.2	0.3590	0.3280	1.0945			4.2	0.3680	0.2640	1.3939	
	5	5.1	0.3450	0.3120	1.1058		5	5.1	0.3590	0.2500	1.4360	1.4260
		5.2	0.3470	0.3160	1.0981			5.2	0.3540	0.2500	1.4160	
T1 LOW NA	1	1.1	0.3700	0.3140	1.1783	1.0709	1	1.1	0.3180	0.2270	1.4009	1.4312
		1.2	0.3720	0.3180	1.1698			1.2	0.3420	0.2340	1.4615	
	2	2.1	0.3500	0.3410	1.0264		2	2.1	0.3490	0.2460	1.4187	1.4305
		2.2	0.3520	0.3410	1.0323			2.2	0.3620	0.2510	1.4422	
	3	3.1	0.3680	0.3200	1.1500		3	3.1	0.3630	0.2580	1.4070	1.4031
		3.2	0.3730	0.3250	1.1477			3.2	0.3330	0.2380	1.3992	
	4	4.1	0.3790	0.3800	0.9974		4	4.1	0.3630	0.2280	1.5921	1.5674
		4.2	0.3790	0.3810	0.9948			4.2	0.3610	0.2340	1.5427	
	5	5.1	0.3640	0.3650	0.9973		5	5.1				#¡DIV/0!
		5.2	0.3350	0.3300	1.0152			5.2				
T5 REG NA	1	1.1	0.3760	0.3130	1.2013	1.1613	1	1.1	0.3360	0.2830	1.1873	1.2715
		1.2	0.4000	0.3280	1.2195			1.2	0.3620	0.2670	1.3558	
	2	2.1	0.4020	0.3120			2	2.1	0.3720	0.2740	1.3577	1.3331
		2.2	0.3630	0.2840				2.2	0.3350	0.2560	1.3086	
	3	3.1	0.3380	0.3050	1.1082		3	3.1	0.3320	0.2700	1.2296	1.2296
		3.2	0.3650	0.3270	1.1162			3.2				
T5 LOW NA	1	1.1	0.3430	0.2610	1.3142	1.1522	1	1.1	0.3610	0.2410	1.4979	1.4915
		1.2	0.3420	0.2530	1.3518			1.2	0.3460	0.2330	1.4850	
	2	2.1	0.3780	0.3190	1.1850		2	2.1	0.3460	0.2590	1.3359	1.3132
		2.2	0.3730	0.3240	1.1512			2.2	0.3420	0.2650	1.2906	
	3	3.1	0.3750	0.3920	0.9566		3	3.1	0.3140	0.2230	1.4081	1.4127
		3.2	0.3750	0.3930	0.9542			3.2	0.3770	0.2660	1.4173	

Table D.14. pH batter– Replication 2

pH							
Study 2 REPLICATION 2							
	No overnight- fresh batter						
		rep 1	**rep 2**	***avg***	**rep 1**	**rep 2**	***avg***
T1 REG NA	min 6	5.85	5.85	5.85	5.86	5.86	5.86
	min 9	5.85	5.85	5.85	5.86	5.85	5.86
	min 12	5.85	5.85	5.85	5.87	5.86	5.87
	min 15	5.84	5.84	5.84	5.87	5.87	5.87
	min 18	5.85	5.85	5.85	5.87	5.87	5.87
	min 21	5.85	5.85	5.85	5.87	5.87	5.87
	min 24	5.87	5.87	5.87	5.88	5.88	5.88
	min 27	5.84	5.85	5.85	5.88	5.88	5.88
T1 LOW NA	min 6	5.85	5.85	5.85	5.85	5.85	5.85
	min 9	5.85	5.85	5.85	5.85	5.85	5.85
	min 12	5.84	5.84	5.84	5.85	5.85	5.85
	min 15	5.84	5.84	5.84	5.85	5.85	5.85
	min 18	5.83	5.83	5.83	5.84	5.84	5.84
	min 21	5.83	5.83	5.83	5.85	5.85	5.85
	min 24						
	min 27						
T5 REG NA	min 6	5.95	5.94	5.95	5.91	5.91	5.91
	min 9	5.93	5.94	5.94	5.94	5.93	5.94
	min 12	5.86	5.85	5.86	5.76	5.75	5.76
	min 15	5.8	5.81	5.81	5.74	5.74	5.74
	min 18	5.77	5.78	5.78	5.78	5.77	5.78
	min 21	5.8	5.79	5.80	5.77	5.77	5.77
	min 24	5.79	5.8	5.80	5.78	5.78	5.78
	min 27	5.78	5.78	5.78	5.78	5.78	5.78
T5 LOW NA	min 6	5.89	5.9	5.90	5.88	5.82	5.85
	min 9	5.9	5.9	5.90	5.85	5.84	5.85
	min 12	5.86	5.87	5.87	5.68	5.67	5.68
	min 15	5.74	5.74	5.74	5.54	5.52	5.53
	min 18	5.63	5.66	5.65	5.51	5.49	5.50
	min 21	5.6	5.6	5.60	5.5	5.5	5.50
	min 24	5.55	5.35	5.45	5.53	5.52	5.53
	min 27	5.53	5.53	5.53	5.55	5.54	5.55

Table D.15. Protein Solubility CB-T 2% – Replication 2

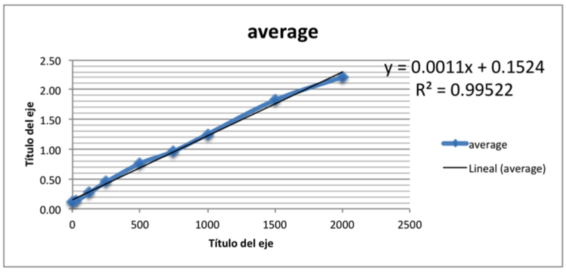
[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.289	2.139	2.21
1500	1.717	1.924	1.82
1000	1.105	1.393	1.25
750	0.838	1.091	0.96
500	0.737	0.781	0.76
250	0.441	0.458	0.45
125	0.263	0.269	0.27
25	0.129	0.129	0.13
0	0.108	0.11	0.109



CB-T 2%					initial [Protein] g/gbatter		0.0466515
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	[Protein] g/gbatter	Prot solubility
19.00	min 3	0.628	0.706	0.667	467.82	0.0187	40.11%
22.50	min6	0.618	0.619	0.6185	344.33	0.0138	29.52%
26.50	min 9	0.61	0.595	0.6025	331.00	0.0132	28.38%
29.20	min 12	0.586	0.609	0.5975	326.83	0.0131	28.02%
30.70	min 15	0.414	0.435	0.4245	182.67	0.0073	15.66%
31.90	min 18	0.364	0.626	0.495	241.42	0.0097	20.70%
32.70	min 21	0.835	0.771	0.803	498.08	0.0199	42.71%
33.30	min 24	0.641	0.646	0.6435	365.17	0.0146	31.31%

Table D.16. Protein Solubility CB-T 1% – Replication 2

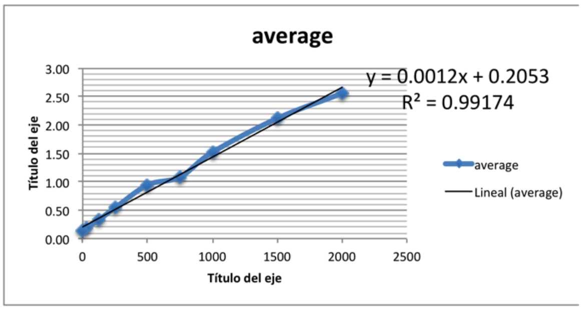
[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.289	2.139	2.21
1500	1.717	1.924	1.82
1000	1.105	1.393	1.25
750	0.838	1.091	0.96
500	0.737	0.781	0.76
250	0.441	0.458	0.45
125	0.263	0.269	0.27
25	0.129	0.129	0.13
0	0.108	0.11	0.109



CB-T 1%					nitial [Protein] g/gbatte	0.04665154	
Tº	time	absorbance 1	absorbance 2	average	[Protein] g/gbatter	g/gbatter	%prot solubility
20.30	min 3	0.587	0.6	0.5935	401.00	0.01604	34.38%
25.70	min6	0.74	0.609	0.6745	391.00	0.01564	33.53%
29.20	min 9	0.555	0.583	0.569	303.08	0.01212	25.99%
31.20	min 12	0.538	0.57	0.554	290.58	0.01162	24.92%
32.50	min 15	0.551	0.587	0.569	303.08	0.01212	25.99%
32.80	min 18	0.591	0.632	0.6115	338.50	0.01354	29.02%
	min 21						
	min 24						

Table D.17. Protein Solubility HB- ¼CFAC 2% – Replication 2

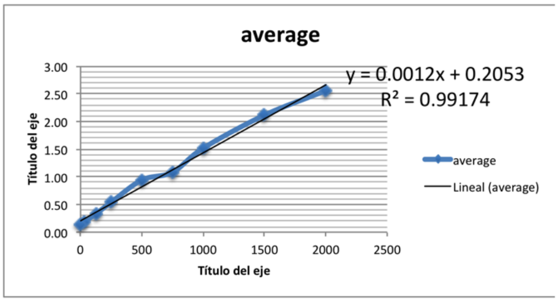
[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.388	2.717	2.55
1500	2.114	2.113	2.11
1000	1.402	1.632	1.52
750	1.044	1.121	1.08
500	0.887	0.997	0.94
250	0.509	0.572	0.54
125	0.335	0.326	0.33
25	0.178	0.183	0.18
0	0.143	0.133	0.138



HB-1/4CFAC					initial [Protein] g/gbatter	0.04665154	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	%prot solubility
-1.90	min 3	0.793	0.811	0.802	497.25	0.0199	42.64%
1.30	min6	0.915	0.839	0.877	559.75	0.0224	47.99%
10.50	min 9	0.707	0.733	0.72	428.92	0.0172	36.78%
17.20	min 12	0.814	0.818	0.816	508.92	0.0204	43.64%
21.40	min 15	0.845	0.887	0.866	550.58	0.0220	47.21%
24.50	min 18	0.837	0.761	0.799	494.75	0.0198	42.42%
26.75	min 21	0.752	0.758	0.755	458.08	0.0183	39.28%
28.40	min 24	0.845	0.835	0.84	528.92	0.0212	45.35%

Table D.18. Protein Solubility HB- ¼CFAC 1% – Replication 2

[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.388	2.717	2.55
1500	2.114	2.113	2.11
1000	1.402	1.632	1.52
750	1.044	1.121	1.08
500	0.887	0.997	0.94
250	0.509	0.572	0.54
125	0.335	0.326	0.33
25	0.178	0.183	0.18
0	0.143	0.133	0.138



HB-1/4CFAC 1%					initial [Protein] ug/ml	0.04665154	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	Prot solubility	% Prot Sol
-1.25	min 3	0.706	0.717	0.7115	421.83	0.0169	36.17%
7.4	min6	0.681	0.714	0.6975	410.17	0.0164	35.17%
15.4	min 9	0.73	0.748	0.739	444.75	0.0178	38.13%
20.75	min 12	0.936	0.923	0.9295	603.50	0.0241	51.75%
24.4	min 15	0.97	1.003	0.9865	651.00	0.0260	55.82%
26.55	min 18	1.054	1.057	1.0555	708.50	0.0283	60.75%
28.2	min 21	0.966	0.947	0.9565	626.00	0.0250	53.67%
29.2	min 24	1.032	1.034	1.033	689.75	0.0276	59.14%

Table D.19. Torsion test CB-T 2% – Replication 2

Torsion Test

STUDY 2 REPLICATION 2

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC REG SODIUM	CB-T 2% min 6	1	12.66	11.9	20.03	1.68	20.10	1.16
		2	13.43	6.1	21.25	0.80		
		3	13.40	10.9	21.20	1.52		
		4	12.96	6.7	20.50	0.89		
		5	11.07	6.7	17.51	0.91		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 9	1	16.64	8.7	26.32	1.16	28.25	1.39
		2	15.79	7.3	24.98	0.96		
		3	18.35	8.8	29.03	1.16		
		4	17.36	7.9	27.46	1.04		
		5	17.74	8.9	28.06	1.18		
		6	20.36	11.50	32.21	1.55		
		7	18.76	18.80	29.68	2.66		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 12	1	20.08	7.60	31.77	0.97	32.04	1.05
		2	20.78	7.80	32.87	0.99		
		3	22.1	8.60	34.96	1.10		
		4	20.22	7.90	31.99	1.01		
		5	19.44	8.60	30.75	1.12		
		6	18.17	8.50	28.74	1.12		
		7	20.96	8.00	33.16	1.02		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 15	1	23.77	9.10	37.60	1.16	36.58	1.19
		2	23.06	8.80	36.48	1.12		
		3	22.16	9.40	35.06	1.22		
		4	24.82	9.50	39.27	1.21		
		5	21.23	8.90	33.59	1.15		
		6	23.61	9.6	37.35	1.24		
		7	23.63	9.00	37.38	1.15		
		8	22.71	9.60	35.93	1.25		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 18	1	21.02	9.00	33.25	1.17	33.06	1.36
		2	21.92	12.80	34.68	1.73		
		3	20.61	13.60	32.61	1.86		
		4	20.31	8.90	32.13	1.16		
		5	21.68	10.80	34.30	1.43		
		6	19.3	8.20	30.53	1.07		
		7	21.45	8.70	33.93	1.12		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 21	1	22.3	8.8	35.28	1.13	33.26	1.18
		2	19.76	8.5	31.26	1.11		
		3	21.31	8.5	33.71	1.09		
		4	19.34	9	30.60	1.18		
		5	20.05	8.9	31.72	1.16		
		6	20.16	8.9	31.89	1.16		
		7	22.82	8.6	36.10	1.10		
		8	22.46	11.5	35.53	1.53		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 24	1	18.68	8.7	29.55	1.15	27.86	1.08
		2	17.15	7.8	27.13	1.02		
		3	19.04	8.4	30.12	1.10		
		4	18.94	8.6	29.96	1.13		
		5	15.06	8.5	23.82	1.15		
		6	16.78	7.1	26.55	0.92		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 27	1	18.34	8.3	29.01	1.09	31.49	1.28
		2	17.49	8.9	27.67	1.19		
		3	21.57	9.3	34.12	1.21		
		4	21.97	9.2	34.76	1.19		
		5	18.23	12.4	28.84	1.70		
		6	20.46	9.7	32.37	1.28		
		7	21.27	9.9	33.65	1.30		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.20. Torsion test CB-T 1% – Replication 2

Torsion Test

STUDY 2 REPLICATION 2

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC LOW SODIUM	CB-T 1% min 6	1	12.57	7.3	19.89	0.99	16.82	0.88
		2	10.29	4.3	16.28	0.56		
		3	7.45	7.4	11.79	1.05		
		4	11.37	7	17.99	0.95		
		5	10.38	6.3	16.42	0.86		
		6	11.75	6.5	18.59	0.87		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 9	1	11.1	6.60	17.56	0.90	17.00	1.04
		2	13.89	7.80	21.97	1.05		
		3	9.69	6.20	15.33	0.85		
		4	9.3	7.10	14.71	0.99		
		5	8.89	6.40	14.06	0.88		
		6	11.6	11.20	18.35	1.58		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 12	1	14	10.50	22.15	1.45	20.90	1.32
		2	14.24	10.20	22.53	1.41		
		3	13.6	8.50	21.52	1.16		
		4	10.71	9.20	16.94	1.29		
		5	12.63	8.90	19.98	1.23		
		6	13.73	10.60	21.72	1.47		
		7	13.58	9.00	21.48	1.23		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 15	1	12.51	8.00	19.79	1.09	20.99	1.31
		2	13.22	11.80	20.91	1.66		
		3	13.24	11.80	20.95	1.66		
		4	13.04	9.40	20.63	1.30		
		5	11.35	7.50	17.96	1.03		
		6	14.61	9	23.11	1.22		
		7	13.43	8.50	21.25	1.16		
		8	14.76	9.90	23.35	1.36		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 18	1	12.07	8.60	19.09	1.19	20.31	1.18
		2	12.32	7.80	19.49	1.06		
		3	13.51	8.60	21.37	1.17		
		4	12.29	8.70	19.44	1.20		
		5	12.85	10.30	20.33	1.43		
		6	14.53	8.50	22.99	1.15		
		7	12.29	7.90	19.44	1.08		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 21	1	11.26	8.1	17.81	1.12	16.51	1.08
		2	11.2	8.1	17.72	1.12		
		3	9.44	8.3	14.93	1.16		
		4	11.31	7.6	17.89	1.04		
		5	9.25	6.9	14.63	0.96		
		6	11.16	7.9	17.66	1.09		
		7	9.43	7.6	14.92	1.06		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 24	1			0.00	0.00	0.00	0.00
		2			0.00	0.00		
		3			0.00	0.00		
		4			0.00	0.00		
		5			0.00	0.00		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 27	1			0.00	0.00	0.00	0.00
		2			0.00	0.00		
		3			0.00	0.00		
		4			0.00	0.00		
		5			0.00	0.00		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.21. Torsion test HB-¼CFAC 2% – Replication 2

Torsion Test

STUDY 2 REPLICATION 2

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T5 PRE Rigor 1/4 CFC REG SODIUM	HB-1/4CFAC 2% min 6	1	24.05	7.2	38.05	0.88	38.54	0.82
		2	22.3	7	35.28	0.86		
		3	24.13	6.5	38.17	0.77		
		4	21.45	6.3	33.93	0.76		
		5	21.41	6.8	33.87	0.84		
		6	28.73	7.1	45.45	0.82		
		7	28.45	7.2	45.01	0.84		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 9	1	41.56	10.10	65.75	1.16	57.95	1.05
		2	37.29	8.30	58.99	0.93		
		3	39.12	8.90	61.89	1.00		
		4	31.11	8.20	49.22	0.97		
		5	34.85	9.60	55.13	1.14		
		6	35.82	9.00	56.67	1.05		
		7	36.66	9.30	58.00	1.08		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 12	1	40.76	10.30	64.48	1.20	62.28	1.10
		2	40.51	9.90	64.09	1.14		
		3	37.76	9.70	59.74	1.13		
		4	37.79	9.30	59.78	1.07		
		5	35.49	8.90	56.15	1.03		
		6	42.28	9.50	66.89	1.07		
		7	40.98	9.30	64.83	1.05		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 15	1	34.49	8.70	54.56	1.01	51.21	0.99
		2	32.49	8.50	51.40	1.00		
		3	34.33	9.30	54.31	1.10		
		4	32.5	8.00	51.42	0.92		
		5	31.01	8.30	49.06	0.98		
		6	29.39	7.8	46.49	0.92		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 18	1	28.94	8.80	45.78	1.07	50.89	1.10
		2	28.94	8.80	45.78	1.07		
		3	34.3	9.00	54.26	1.06		
		4	33.61	9.50	53.17	1.14		
		5	34.34	9.60	54.33	1.15		
		6	33.59	9.10	53.14	1.08		
		7	32.12	8.90	50.81	1.06		
		8	31.49	9.50	49.82	1.16		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 21	1	29.07	8.7	45.99	1.06	45.70	1.03
		2	28.49	7.7	45.07	0.91		
		3	27.53	8.8	43.55	1.09		
		4	27.50	8.4	43.51	1.03		
		5	30.09	8.7	47.60	1.05		
		6	28.48	9	45.06	1.11		
		7	31.06	8.2	49.14	0.97		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 24	1	28.85	8.9	45.64	1.09	42.94	1.08
		2	25.89	9.4	40.96	1.19		
		3	24.39	8.6	38.58	1.08		
		4	27.22	7.7	43.06	0.92		
		5	28.11	8.3	44.47	1.01		
		6	24.39	8.3	38.58	1.04		
		7	31.14	9.9	49.26	1.22		
		8						
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 27	1	26.92	8.4	42.59	1.03	42.14	1.02
		2	26.57	8.6	42.03	1.06		
		3	26.15	8.9	41.37	1.11		
		4	25.96	8	41.07	0.98		
		5	28.59	7.8	45.23	0.93		
		6	25.62	8	40.53	0.98		
		7						
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.22. Torsion test HB-¼CFAC 1% – Replication 2

Torsion Test

STUDY 2 REPLICATION 2

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T5 PRE Rigor 1/4 CFC LOW SODIUM	HB-1/4CFAC 1% min 6	1	16.72	5	26.45	0.61	26.68	0.69
		2	26.14	6.5	41.35	0.75		
		3	15.29	5.2	24.19	0.65		
		4	15.16	6.1	23.98	0.79		
		5	16.2	5.4	25.63	0.67		
		6	11.67	5	18.46	0.65		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 9	1	22.81	7.50	36.09	0.93	30.00	0.65
		2	23.73	6.50	37.54	0.77		
		3	21.38	6.70	33.82	0.82		
		4	20.9	5.90	33.06	0.71		
		5	22.5	7.00	35.60	0.86		
		6	26.7	6.90	42.24	0.81		
		7	28.68	6.90	45.37	0.79		
		8	22.95	7.00	36.31	0.85		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 12	1	17.28	6.40	27.34	0.81	35.21	0.90
		2	26.44	7.90	41.83	0.96		
		3	23.01	8.40	36.40	1.06		
		4	26.85	7.60	42.48	0.91		
		5	20.04	6.30	31.70	0.77		
		6	19.93	6.80	31.53	0.85		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 15	1	21.7	7.00	34.33	0.87	32.24	0.92
		2	19.04	7.30	30.12	0.93		
		3	22.59	6.80	35.74	0.83		
		4	15.21	6.90	24.06	0.91		
		5	22.35	9.3	35.36	1.20		
		6	21.39	6.50	33.84	0.79		
		7						
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 18	1	16.52	6.00	26.13	0.76	31.24	0.85
		2	23.04	7.70	36.45	0.96		
		3	19.28	6.90	30.50	0.87		
		4	20.94	7.40	33.13	0.93		
		5	22.35	6.80	35.36	0.83		
		6	21.83	6.60	34.54	0.80		
		7	14.25	6.30	22.54	0.82		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 21	1	14.25	6.3	22.54	0.82	25.84	0.83
		2	15.21	6.8	24.06	0.89		
		3	15.91	6.6	25.17	0.85		
		4	20.31	6.8	32.13	0.85		
		5	15.11	6.5	23.90	0.85		
		6	16.78	6.2	26.55	0.79		
		7	16.78	6.2	26.55	0.79		
		8						
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 24	1	11.49	6.6	18.18	0.89	25.62	0.92
		2	19.76	7.6	31.26	0.97		
		3	17.87	7.3	28.27	0.94		
		4	16.96	7.2	26.83	0.94		
		5	11.46	6.1	18.13	0.82		
		6	18.14	7.3	28.70	0.94		
		7	17.69	7.3	27.99	0.94		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 27	1	16.72	7.7	26.45	1.01	25.54	1.02
		2	14.53	7.6	22.99	1.02		
		3	17.18	7.8	27.18	1.02		
		4			0.00	0.00		
		5			0.00	0.00		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.23. Batter temperature monitoring – Replication 3

Study 2 Replication 3

Initial meat T	Sample Name	real time	mixing time	Temperature ºC	rpm	notes
5.0 +- 0.5ºC			3	11		
T1 Regular Salt	CB-T 2% MIN 6		6	19.9		72-81
	CB-T 2% MIN 9		9	25.5		
	CB-T 2% MIN 12		12	28.3		
	CB-T 2% MIN 15		15	31.8		74-82
	CB-T 2% MIN 18		18	33.8		
	CB-T 2% MIN 21		21	35.5		74-82
	CB-T 2% MIN 24		24	36.8		
	CB-T 2% MIN 27		27	37.6		

Initial meat T	Sample Name	real time	mixing time	Temperature ºC	rpm	notes
(-0.5) +- 1ºC			2	-2.5		
T5 Regular Salt	HB-1/4CFAC 2% MIN 6		6	-1.6		
	HB-1/4CFAC 2% MIN 9		9	9.4		76
	HB-1/4CFAC 2% MIN 12		12	17		72-81
	HB-1/4CFAC 2% MIN 15		15	23.1		
	HB-1/4CFAC 2% MIN 18		18	27.1		
	HB-1/4CFAC 2% MIN 21		21	30.5		74-82
	HB-1/4CFAC 2% MIN 24		24	32		
	HB-1/4CFAC 2% MIN 27		27	33.7		74-82

Initial meat T	Sample Name	real time	mixing time	Temperature ºC	rpm	notes
5 +- 0.5ºC			3	10.8		
T1 Low Salt	CB-T 1% MIN 6		6	20		
	CB-T 1% MIN 9		9	26		72-81
	CB-T 1% MIN 12		12	29.6		
	CB-T 1% MIN 15		15	33		
	CB-T 1% MIN 18		18	35.5		74-82
	CB-T 1% MIN 21		21	37.4		
	CB-T 1% MIN 24		24	38.7		74-82
	CB-T 1% MIN 27		27	39.6		

Initial meat T	Sample Name	real time	mixing time	Temperature ºC	rpm	notes
(-1.5) +- 0.5ºC						
T5 Reg.2 Salt (For Rep 4)	HB-1/4CFAC 2% MIN 6		6	-1.5		
	HB-1/4CFAC 2% MIN 9		9	11.3		72-81
	HB-1/4CFAC 2% MIN 12		12	19.1		
	HB-1/4CFAC 2% MIN 15		15	24.8		
	HB-1/4CFAC 2% MIN 18		18	28.8		74-82
	HB-1/4CFAC 2% MIN 21		21	31.5		
	HB-1/4CFAC 2% MIN 24		24	33.4		74-82
	HB-1/4CFAC 2% MIN 27		27	34.6		

Table D.24. Raw meat pH – Replication 3

pH									
STUDY 2 REPLICATION 3									
Sample Name	**before chilling frozen raw meat**					**after chilling frozen raw meat**			
		rep 1	**rep 2**	***avg***	***avg***	**rep 1**	**rep 2**	***avg***	***avg***
CB-T 2%	1	5.99	6.01	***6.00***	***5.95***	5.76	5.73	***5.75***	***5.76***
	2	5.89	5.89	***5.89***		5.77	5.85	***5.81***	
	3	5.93	5.99	***5.96***		5.71	5.71	***5.71***	
CB-T 1%	1	5.92	5.83	***5.88***	***5.88***	5.83	5.81	***5.82***	***5.73***
	2	5.74	5.75	***5.75***		5.66	5.66	***5.66***	
	3	6.02	6.01	***6.02***		5.72	5.72	***5.72***	
HB-1/4CFAC 2%	1	6.09	6.08	***6.09***	***6.20***	5.93	5.89	***5.91***	***5.96***
	2	5.94	5.83	***5.89***		5.87	5.90	***5.89***	
	3	6.61	6.64	***6.63***		6.03	6.12	***6.08***	
HB-1/4CFAC 2% REP 4	1	6.16	6.15	***6.16***	***6.10***	5.86	5.90	***5.88***	***5.84***
	2	6.18	6.12	***6.15***		5.74	5.78	***5.76***	
	3	6.01	5.95	***5.98***		5.87	5.89	***5.88***	

Table D.25. Raw meat R-value – Replication 3

study 2 replication 3

R-value												
	sample 3 g, wave leth, 250 and 260 nm											
Frozen muscle BEFORE CHILLING					Frozen muscle AFTER CHILLING							
Sample Name	sample No.	trial No.	250 nm	260 nm	r-value	average	sample No.	trial No.	250 nm	260 nm	r-value	average
blank(ref.)			0	-0.049						-0.049		
CB-T 2%	1	1.1	0.3810	0.3450	1.1043	1.0570	1	1.1	0.4020	0.2990	1.3445	1.3135
		1.2	0.3910	0.3590	1.0891			1.2	0.3360	0.2620	1.2824	
	2	2.1	0.3590	0.3340	1.0749		2	2.1	0.3780	0.2750	1.3745	1.3299
		2.2	0.3650	0.3400	1.0735			2.2	0.3380	0.2630	1.2852	
	3	3.1	0.3710	0.3730	0.9946		3	3.1	0.3800	0.2760	1.3768	1.3806
		3.2	0.3660	0.3640	1.0055			3.2	0.3710	0.2680	1.3843	
CB-T 2%	1	1.1	0.4070	0.4230	0.9622	1.0447	1	1.1	0.3950	0.3060	1.2908	1.2908
		1.2	0.3240	0.3440	0.9419			1.2	0.4040	0.3130	1.2907	
	2	2.1	0.3620	0.3150	1.1492		2	2.1	0.3450	0.2510	1.3745	1.3839
		2.2	0.3710	0.3140	1.1815			2.2	0.3790	0.2720	1.3934	
	3	3.1	0.3970	0.3870	1.0258		3	3.1	0.3780	0.2750	1.3745	1.3794
		3.2	0.3880	0.3850	1.0078			3.2	0.3710	0.2680	1.3843	
				(0.0460)						(0.0460)		
HB-1/4CFAC 2%	1	1.1	0.3950	0.3920	1.0077	1.0217	1	1.1	0.3970	0.3200	1.2406	1.2369
		1.2	0.3680	0.3560	1.0337			1.2	0.4020	0.3260	1.2331	
	2	2.1	0.4030	0.3510	1.1481		2	2.1	0.4000	0.3010	1.3289	1.3311
		2.2	0.3530	0.3100	1.1387			2.2	0.4280	0.3210	1.3333	
	3	3.1	0.3950	0.4330	0.9122		3	3.1	0.4380	0.4120	1.0631	1.0562
		3.2	0.3960	0.4450	0.8899			3.2	0.4040	0.3850	1.0494	
HB-1/4CFAC 2% REP 4	1	1.1	0.3820	0.3700	1.0324	1.0063	1	1.1	0.3450	0.2830	1.2191	1.2259
		1.2	0.3800	0.3780	1.0053			1.2	0.3550	0.2880	1.2326	
	2	2.1	0.3960	0.3950	1.0025		2	2.1	0.4180	0.3150	1.3270	1.3268
		2.2	0.3700	0.3700	1.0000			2.2	0.3900	0.2940	1.3265	
	3	3.1	0.3800	0.3800	1.0000		3	3.1	0.3960	0.3190	1.2414	1.2414
		3.2	0.3970	0.3980	0.9975			3.2				

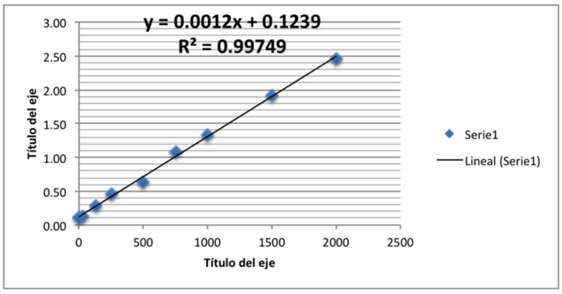
Table D.26. Batter pH – Replication 3

pH								
REPLICATION 1								
	No overnight- fresh batter				Overnight batter			
		rep 1	rep 2	*avg*		rep 1	rep 2	*avg*
CB-T 2%	min 3	5.73	5.75	5.74		5.73	5.75	5.74
	min 6	5.75	5.76	5.755		5.77	5.76	5.765
	min 9	5.76	5.76	5.76		5.77	5.77	5.77
	min 12	5.78	5.77	5.775		5.79	5.78	5.785
	min 15	5.77	5.78	5.775		5.78	5.78	5.78
	min 18	5.78	5.78	5.78		5.78	5.79	5.785
	min 21	5.79	5.79	5.79		5.79	5.79	5.79
	min 24	5.75	5.76	5.755		5.8	5.8	5.8
CB-T 1%	min 3	5.72	5.73	5.725		5.74	5.75	5.745
	min 6	5.75	5.75	5.75		5.76	5.76	5.76
	min 9	5.75	5.75	5.75		5.77	5.78	5.775
	min 12	5.76	5.76	5.76		5.78	5.77	5.775
	min 15	5.76	5.76	5.76		5.77	5.77	5.77
	min 18	5.76	5.76	5.76		5.77	5.77	5.77
	min 21	5.73	5.74	5.735		5.78	5.77	5.775
	min 24	5.76	5.75	5.755		5.78	5.78	5.78
HB- 1/4 CFAC 2 %	min 3	6.02	6.02	6.02		6.04	6.04	6.04
	min 6	5.93	5.93	5.93		5.75	5.75	5.75
	min 9	5.84	5.84	5.84		5.69	5.69	5.69
	min 12	5.76	5.76	5.76		5.7	5.7	5.70
	min 15	5.76	5.76	5.76		5.74	5.74	5.74
	min 18	5.74	5.74	5.74		5.71	5.71	5.71
	min 21	5.75	5.75	5.75		5.72	5.72	5.72
	min 24	5.72	5.72	5.72		5.74	5.74	5.74
HB- 1/4 CFAC 2 % REP 4	min 3	5.89	5.9	5.895		5.87	5.88	5.875
	min 6	5.92	5.92	5.92		5.88	5.88	5.88
	min 9	5.79	5.77	5.78		5.75	5.75	5.75
	min 12	5.65	5.65	5.65		5.65	5.64	5.645
	min 15	5.63	5.62	5.625		5.63	5.62	5.625
	min 18	5.61	5.6	5.605		5.6	5.6	5.6
	min 21	5.61	5.6	5.605		5.61	5.6	5.605
	min 24	5.62	5.61	5.615		5.61	5.6	5.605

Table D.27. Protein solubility CB-T 2% – Replication 3

T1 REG

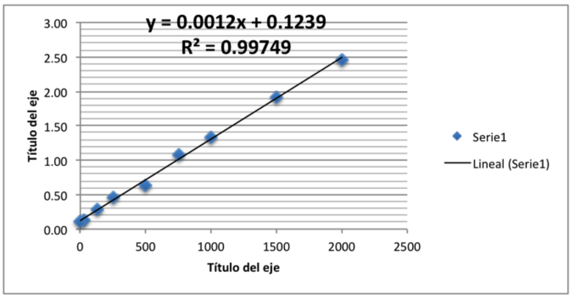
[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.465		2.47
1500	1.92	1.91	1.92
1000	1.234	1.425	1.33
750	1.052	1.089	1.07
500	0.712	0.562	0.64
250	0.369	0.563	0.47
125	0.279	0.271	0.28
25	0.127	0.129	0.13
0	0.115	0.116	0.12



CB-T 2%					initial [Protein] g/gbatter	0.046651538	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	%prot solubility
19.90	min 3	0.636	0.64	0.638	428.42	0.0171	36.73%
25.50	min6	0.454	0.463	0.4585	278.83	0.0112	23.91%
28.30	min 9	0.663	0.693	0.678	461.75	0.0185	39.59%
31.80	min 12	0.657	0.675	0.666	451.75	0.0181	38.73%
33.80	min 15	0.668	0.691	0.6795	463.00	0.0185	39.70%
35.50	min 18	0.615	0.635	0.625	417.58	0.0167	35.80%
36.80	min 21	0.617	0.7	0.6585	445.50	0.0178	38.20%
37.60	min 24	0.57	0.606	0.588	386.75	0.0155	33.16%

Table D.28. Protein solubility CB-T 1% – Replication 3

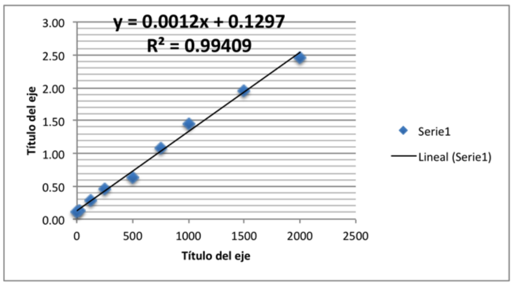
[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.465		2.47
1500	1.92	1.91	1.92
1000	1.234	1.425	1.33
750	1.052	1.089	1.07
500	0.712	0.562	0.64
250	0.369	0.563	0.47
125	0.279	0.271	0.28
25	0.127	0.129	0.13
0	0.115	0.116	0.12



CB-T 1%					initial [Protein] g/gbatter	0.046651538	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	%prot solubility
19.90	min 3	0.565	0.533	0.549	354.25	0.0142	30.37%
25.50	min6	0.552	0.511	0.5315	339.67	0.0136	29.12%
28.30	min 9	0.601	0.52	0.5605	363.83	0.0146	31.20%
31.80	min 12	0.6	0.619	0.6095	404.67	0.0162	34.70%
33.80	min 15	0.649	0.665	0.657	444.25	0.0178	38.09%
35.50	min 18	0.583	0.586	0.5845	383.83	0.0154	32.91%
36.80	min 21	0.569	0.584	0.5765	377.17	0.0151	32.34%
37.60	min 24	0.606	0.607	0.6065	402.17	0.0161	34.48%

Table D.29. Protein solubility HB-¼CFAC 2% – Replication 3

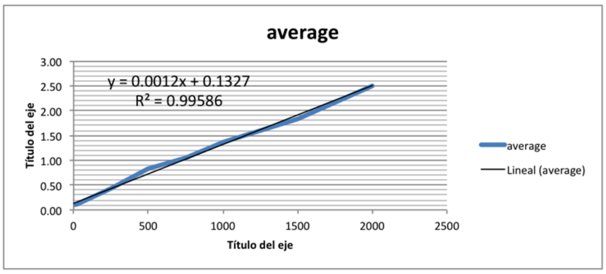
[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.465	2.582	2.47
1500	1.92	2.001	1.96
1000	1.489	1.425	1.46
750	1.052	1.089	1.07
500	0.712	0.562	0.64
250	0.369	0.563	0.47
125	0.279	0.271	0.28
25	0.127	0.129	0.13
0	0.115	0.116	0.12



HB-1/4CFAC 2%					initial [Protein] g/gbatter	0.046651538	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	%prot solubility
19.90	min 3	0.793	0.791	0.792	551.92	0.0221	47.32%
25.50	min6	0.85	0.844	0.847	597.75	0.0239	51.25%
28.30	min 9	0.844	0.855	0.8495	599.83	0.0240	51.43%
31.80	min 12	0.867	0.842	0.8545	604.00	0.0242	51.79%
33.80	min 15	0.801	0.817	0.809	566.08	0.0226	48.54%
35.50	min 18	0.816	0.852	0.834	586.92	0.0235	50.32%
36.80	min 21	0.82	0.832	0.826	580.25	0.0232	49.75%
37.60	min 24	0.716	0.908	0.812	568.58	0.0227	48.75%

Table D.30. Protein solubility HB-¼CFAC 1% – Replication 3

[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.504	1.935	2.50
1500	1.725	1.943	1.83
1000	1.291	1.458	1.37
750	1.053	1.065	1.06
500	0.782	0.85	0.82
250	0.445	0.434	0.44
125	0.26	0.256	0.26
25	0.11	0.111	0.11
0	0.099	0.1	0.10



HB-1/4CFAC 1%					initial [Protein] g/gbatter	0.046651538	
	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	%prot solubility
	min 3	0.671	0.648	0.6595	439.00	0.0176	37.64%
	min6	0.66	0.66	0.66	439.42	0.0176	37.68%
	min 9	0.667	0.663	0.665	443.58	0.0177	38.03%
	min 12	0.647	0.644	0.6455	427.33	0.0171	36.64%
	min 15	0.912	0.897	0.9045	643.17	0.0257	55.15%
	min 18	0.859	0.891	0.875	618.58	0.0247	53.04%
	min 21	0.857	0.868	0.8625	608.17	0.0243	52.15%
	min 24	0.893	0.916	0.9045	643.17	0.0257	55.15%

Table D.31. Torsion test CB-T 2% – Replication 3

Torsion Test

STUDY 2 REPLICATION 3

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC REG SODIUM	CB-T 2% min 6	1	17.36	7.8	27.46	1.02	24.97	1.15
		2	12.56	8.2	19.87	1.12		
		3	17.17	8.3	27.16	1.10		
		4	18.98	8.7	30.03	1.14		
		5	16.46	7.8	26.04	1.03		
		6	15.59	8.2	24.66	1.10		
		7	12.37	11	19.57	1.54		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 9	1	18.3	8.90	28.95	1.18	29.16	1.32
		2	17.39	9.90	27.51	1.34		
		3	19.06	9.70	30.15	1.29		
		4	16.31	9.00	25.80	1.21		
		5	18.71	11.90	29.60	1.62		
		6	20.82	9.90	32.94	1.31		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 12	1	18.74	9.9	29.65	1.32	30.03	1.27
		2	17.56	9.00	27.78	1.20		
		3	20.08	9.90	31.77	1.31		
		4	20.02	9.70	31.67	1.28		
		5	18.12	9.30	28.67	1.24		
		6	19.38	9.30	30.66	1.23		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 15	1	18.82	9.50	29.77	1.26	27.91	1.31
		2	18.35	10.00	29.03	1.34		
		3	16.51	9.40	26.12	1.27		
		4	16.04	9.80	25.38	1.33		
		5	18.48	10.10	29.24	1.36		
		6	17.66	9.5	27.94	1.27		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 18	1	17.08	10.90	27.02	1.49	24.21	1.35
		2	16.73	10.30	26.47	1.40		
		3	16.22	9.90	25.66	1.35		
		4	11.18	8.50	17.69	1.18		
		5			0.00	0.00		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 21	1	15.76	9.7	24.93	1.32	25.07	1.36
		2	15.94	10.3	25.22	1.41		
		3			0.00	0.00		
		4			0.00	0.00		
		5			0.00	0.00		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 24	1	10.21	8.1	16.15	1.13	19.00	1.32
		2	11.75	8.6	18.59	1.19		
		3	10.84	10	17.15	1.41		
		4	12.38	10.6	19.59	1.48		
		5	14.86	10.3	23.51	1.42		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 27	1	13.43	11.2	21.25	1.56	21.58	1.51
		2	13.35	11.2	21.12	1.57		
		3	13.82	11.2	21.86	1.56		
		4	13.68	11.2	21.64	1.56		
		5	12.67	10.4	20.04	1.45		
		6	14.88	9.9	23.54	1.36		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.32. Torsion test CB-T 1% – Replication 3

Torsion Test

STUDY 2 REPLICATION 3

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC LOW SODIUM	CB-T 1% min 6	1	13.69	6.4	21.66	0.84	23.28	0.89
		2	12.84	5.4	20.31	0.70		
		3	16.88	7.3	26.70	0.95		
		4	14.2	7.1	22.46	0.94		
		5	15.97	7.6	25.26	1.00		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 9	1	16.72	7.30	26.45	0.95	26.54	1.03
		2	18.41	8.60	29.12	1.13		
		3	16.39	8.00	25.93	1.06		
		4	17.45	7.60	27.61	0.99		
		5	18.43	8.50	29.16	1.12		
		6	13.25	6.80	20.96	0.91		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 12	1	16.31	7.90	25.80	1.05	29.14	1.30
		2	19.53	9.00	30.90	1.18		
		3	20.61	13.30	32.61	1.82		
		4	17.82	9.20	28.19	1.23		
		5	17.82	9.20	28.19	1.23		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 15	1	18.04	8.50	28.54	1.12	27.05	1.19
		2	16.57	8.10	26.21	1.07		
		3	16.57	8.10	26.21	1.07		
		4	15.92	8.10	25.19	1.08		
		5	17.82	9.20	28.19	1.23		
		6	17.66	11.5	27.94	1.57		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 18	1	16.88	9.30	26.70	1.25	26.82	1.23
		2	16.41	8.50	25.96	1.13		
		3	19.2	11.00	30.37	1.49		
		4	16.39	8.50	25.93	1.13		
		5	15.9	8.40	25.15	1.12		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 21	1	14.4	7.6	22.78	1.02	22.33	1.20
		2	14.64	8.5	23.16	1.15		
		3	14.93	11.1	23.62	1.54		
		4	12.74	8.6	20.15	1.18		
		5	13.85	8.2	21.91	1.11		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 24	1	16.64	8.6	26.32	1.15	24.40	1.17
		2	13.8	8.4	21.83	1.14		
		3	15.63	8.8	24.73	1.19		
		4	15.63	8.9	24.73	1.20		
		5			0.00	0.00		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 27	1	11.17	7.7	17.67	1.06	19.27	1.49
		2	13.8	12.1	21.83	1.70		
		3	11.58	12	18.32	1.70		
		4			0.00	0.00		
		5			0.00	0.00		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.33. Torsion test HB-¼CFAC 2% – Replication 3

Torsion Test

STUDY 2 REPLICATION 3

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T5 PRE Rigor 1/4 CFC REG SODIUM	HB-1/4CFAC 2% min 6	1	28.64	8.4	45.31	1.02	43.21	1.01
		2	30.55	7.7	48.33	0.90		
		3	30.21	8.8	47.79	1.06		
		4	26.61	7.3	42.10	0.87		
		5	18.6	9.1	29.43	1.21		
		6	29.28	8.3	46.32	1.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 9	1	40.23	9.00	63.64	1.01	59.68	0.89
		2	40.8	8.60	64.55	0.94		
		3	35	7.40	55.37	0.81		
		4	40.67	7.90	64.34	0.84		
		5	38.87	8.30	61.49	0.91		
		6	29.47	6.40	46.62	0.71		
		7	39.02	8.90	61.73	1.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 12	1	33.05	7.90	52.29	0.90	54.82	0.96
		2	37.48	8.40	59.29	0.94		
		3	37.48	8.40	59.29	0.94		
		4	34.3	8.20	54.26	0.94		
		5	31.77	9.40	50.26	1.14		
		6	33.81	8.20	53.49	0.94		
		7	34.67	8.20	54.85	0.94		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 15	1	41.8	9.50	66.13	1.07	54.72	0.96
		2	37.6	8.30	59.48	0.93		
		3	31.4	7.40	49.67	0.84		
		4	35.48	8.00	56.13	0.90		
		5	33.94	8.40	53.69	0.97		
		6	35.14	8.6	55.59	0.99		
		7	26.77	8.40	42.35	1.03		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 18	1	25.24	6.90	39.93	0.82	36.97	0.70
		2	31.85	8.00	50.39	0.93		
		3	31.39	7.9	49.66	0.92		
		4	27.94	7.60	44.20	0.90		
		5	27.03	7.30	42.76	0.86		
		6	32.13	7.80	50.83	0.90		
		7	29.29	7.70	46.34	0.91		
		8	28.81	6.90	45.58	0.79		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 21	1	18.57	6.9	29.38	0.88	32.70	0.92
		2	22.39	7.9	35.42	0.99		
		3	21.58	7.6	34.14	0.96		
		4	18.79	7.8	29.73	1.01		
		5	22.74	6.9	35.97	0.84		
		6	22.74	6.9	35.97	0.84		
		7	17.9	7	28.32	0.90		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 24	1	19.36	8.2	30.63	1.06	30.72	1.07
		2	24.02	9.1	38.00	1.16		
		3	22.98	8	36.35	1.00		
		4	15.35	7	24.28	0.92		
		5	18.09	7.3	28.62	0.94		
		6	16.71	9.8	26.44	1.33		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 2% min 27	1	16.28	7.6	25.75	1.00	28.25	0.94
		2	20.21	8.4	31.97	1.09		
		3	16.84	6.6	26.64	0.85		
		4	18.01	7	28.49	0.90		
		5	17.95	6.8	28.40	0.87		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.34. Torsion test HB-¼CFAC 1% – Replication 3

Torsion Test

STUDY 2 REPLICATION 3

T5 PRE Rigor 1/4 CFC REG.2 REP4 SODIUM

Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
HB-1/4CFAC 2% min 6	1	22.33	8.2	35.33	1.04	34.14	0.94
	2	22.12	6.7	34.99	0.82		
	3	19.5	6.9	30.85	0.87		
	4	23.24	7.9	36.77	0.99		
	5	22.77	6.9	36.02	0.84		
	6	18.21	7	28.81	0.89		
	7	21.97	8.5	34.76	1.09		
	8	22.52	7.7	35.63	0.96		
	9			0.00	0.00		
	10			0.00	0.00		
HB-1/4CFAC 2% min 9	1	25.26	7.70	39.96	0.94	43.84	1.50
	2	26.89	8.60	42.54	1.06		
	3	26.27	9.00	41.56	1.13		
	4	27.45	8.90	43.43	1.10		
	5	26.46	9.60	41.86	1.21		
	6	29.78	9.40	47.11	1.16		
	7	29.78	29.78	47.11	4.21		
	8	29.78	9.40	47.11	1.16		
	9			0.00	0.00		
	10			0.00	0.00		
HB-1/4CFAC 2% min 12	1	24.13	8.40	38.17	1.05	39.40	1.07
	2	25.71	8.10	40.67	1.00		
	3	23.87	8.20	37.76	1.03		
	4	25.25	8.30	39.95	1.03		
	5	25.37	8.90	40.14	1.12		
	6	23.73	8.30	37.54	1.04		
	7	24.48	9.50	38.73	1.22		
	8	26.72	8.90	42.27	1.11		
	9			0.00	0.00		
	10			0.00	0.00		
HB-1/4CFAC 2% min 15	1	20.43	7.60	32.32	0.97	32.66	1.20
	2	22.19	14.40	35.10	1.97		
	3	20.57	8.00	32.54	1.02		
	4	19.58	9.50	30.98	1.26		
	5	21.74	8.50	34.39	1.09		
	6	18.58	8	29.39	1.04		
	7	19.73	8.60	31.21	1.12		
	8	22.35	8.90	35.36	1.14		
	9			0.00	0.00		
	10			0.00	0.00		
HB-1/4CFAC 2% min 18	1	20.97	9.20	33.17	1.20	36.58	1.25
	2	20.97	9.20	33.17	1.20		
	3	22.59	9.90	35.74	1.29		
	4	22.21	9.30	35.14	1.21		
	5	26.82	10.10	42.43	1.29		
	6	23.71	10.00	37.51	1.30		
	7	24.57	10.00	38.87	1.29		
	8			0.00	0.00		
	9			0.00	0.00		
	10			0.00	0.00		
HB-1/4CFAC 2% min 21	1	25.86	10	40.91	1.28	37.56	1.24
	2	22.46	9.9	35.53	1.29		
	3	23.11	9	36.56	1.15		
	4	26.85	9.9	42.48	1.26		
	5	24.57	9.6	38.87	1.23		
	6	21.26	9.1	33.63	1.18		
	7	22.1	9.6	34.96	1.25		
	8			0.00	0.00		
	9			0.00	0.00		
	10			0.00	0.00		
HB-1/4CFAC 2% min 24	1	15.11	8	23.90	1.07	28.85	1.16
	2	19.08	9.1	30.18	1.20		
	3	24.33	10	38.49	1.29		
	4	15.7	8.6	24.84	1.16		
	5	16.96	8.3	26.83	1.10		
	6			0.00	0.00		
	7			0.00	0.00		
	8			0.00	0.00		
	9			0.00	0.00		
	10			0.00	0.00		
HB-1/4CFAC 2% min 27	1	12.87	7.9	20.36	1.07	23.80	1.12
	2	13.87	8.7	21.94	1.19		
	3	14.86	7.6	23.51	1.01		
	4	18.58	9.2	29.39	1.22		
	5			0.00	0.00		
	6			0.00	0.00		
	7			0.00	0.00		
	8			0.00	0.00		
	9			0.00	0.00		
	10			0.00	0.00		

Table D.35. Batter temperature monitoring – Replication 4

Study 2 Replication 4

	Sample Name	real time	mixing time	Temperature ºC	rpm	notes
		3	0	9.5		
T1 Regular Salt	CB-T 2% MIN 6	6	3	16.4		72-81
	CB-T 2% MIN 9	9	6	20.9		
	CB-T 2% MIN 12	12	9	23.9		
	CB-T 2% MIN 15	15	12	26		74-82
	CB-T 2% MIN 18	18	15	27.8		
	CB-T 2% MIN 21	21	18	29.3		74-82
	CB-T 2% MIN 24	24	21	30.8		
	CB-T 2% MIN 27	27	24	31.3		

	Sample Name	real time	mixing time	Temperature ºC	rpm	notes
		3	0	-1.3		
T5 Low Salt Rep 3	HB-1/4CFAC 2% MIN 6	6	3	-0.9		
	HB-1/4CFAC 2% MIN 9	9	6	5.6		76
	HB-1/4CFAC 2% MIN 12	12	9	12.2		
	HB-1/4CFAC 2% MIN 15	15	12	16.6		
	HB-1/4CFAC 2% MIN 18	18	15	19.9		
	HB-1/4CFAC 2% MIN 21	21	18	22.5		
	HB-1/4CFAC 2% MIN 24	24	21	24.6		
	HB-1/4CFAC 2% MIN 27	27	24	25.8		

	Sample Name	real time	mixing time	Temperature ºC	rpm	notes
		3	0	9.2		
T1 Low Salt	CB-T 1% MIN 6	6	3	16.2		
	CB-T 1% MIN 9	9	6	21		
	CB-T 1% MIN 12	12	9	24.2		
	CB-T 1% MIN 15	15	12	26.4		
	CB-T 1% MIN 18	18	15	28.7		
	CB-T 1% MIN 21	21	18	29.8		
	CB-T 1% MIN 24	24	21	31.4		
	CB-T 1% MIN 27	27	24	32.6		

	Sample Name	real time	mixing time	Temperature ºC	rpm	notes
		3	0	-1.5		
T5 Low Salt	HB-1/4CFAC 1% MIN 6	6	3	-1		
	HB-1/4CFAC 1% MIN 9	9	6	0.4		
	HB-1/4CFAC 1% MIN 12	12	9	8.5		
	HB-1/4CFAC 1% MIN 15	15	12	13.8		
	HB-1/4CFAC 1% MIN 18	18	15	18.2		
	HB-1/4CFAC 1% MIN 21	21	18	21		
	HB-1/4CFAC 1% MIN 24	24	21	23.6		
	HB-1/4CFAC 1% MIN 27	27	24	25.5		

Table D.36. Batter pH during mincing– Replication 4

pH								
STUDY 2REPLICATION 4								
	No overnight- fresh batter				Overnight batter			
		rep 1	rep 2	*avg*		rep 1	rep 2	*avg*
CB-T 2%	min 6	5.73	5.75	5.74		5.73	5.75	5.74
	min 9	5.75	5.76	5.755		5.77	5.76	5.765
	min 12	5.76	5.76	5.76		5.77	5.77	5.77
	min 15	5.78	5.77	5.775		5.79	5.78	5.785
	min 18	5.77	5.78	5.775		5.78	5.78	5.78
	min 21	5.78	5.78	5.78		5.78	5.79	5.785
	min 24	5.79	5.79	5.79		5.79	5.79	5.79
	min 27	5.75	5.76	5.755		5.8	5.8	5.8
CB-T 1%	min 6	5.72	5.73	5.725		5.74	5.75	5.745
	min 9	5.75	5.75	5.75		5.76	5.76	5.76
	min 12	5.75	5.75	5.75		5.77	5.78	5.775
	min 15	5.76	5.76	5.76		5.78	5.77	5.775
	min 18	5.76	5.76	5.76		5.77	5.77	5.77
	min 21	5.76	5.76	5.76		5.77	5.77	5.77
	min 24	5.73	5.74	5.735		5.78	5.77	5.775
	min 27	5.76	5.75	5.755		5.78	5.78	5.78
HB- 1/4 CFAC 1 % Rep 3	min 6	6.02	6.02	6.02		6.04	6.04	6.04
	min 9	5.93	5.93	5.93		5.75	5.75	5.75
	min 12	5.84	5.84	5.84		5.69	5.69	5.69
	min 15	5.76	5.76	5.76		5.7	5.7	5.70
	min 18	5.76	5.76	5.76		5.74	5.74	5.74
	min 21	5.74	5.74	5.74		5.71	5.71	5.71
	min 24	5.75	5.75	5.75		5.72	5.72	5.72
	min 27	5.72	5.72	5.72		5.74	5.74	5.74
HB- 1/4 CFAC 1 % REP 4	min 6	5.89	5.9	5.895		5.87	5.88	5.875
	min 9	5.92	5.92	5.92		5.88	5.88	5.88
	min 12	5.79	5.77	5.78		5.75	5.75	5.75
	min 15	5.65	5.65	5.65		5.65	5.64	5.645
	min 18	5.63	5.62	5.625		5.63	5.62	5.625
	min 21	5.61	5.6	5.605		5.6	5.6	5.6
	min 24	5.61	5.6	5.605		5.61	5.6	5.605
	min 27	5.62	5.61	5.615		5.61	5.6	5.605

Table D.37. Raw meat pH – Replication 4

pH									
study 2 replication 4									
Sample Name	before chilling					after chilling frozen raw meat			
		rep 1	rep 2	*avg*	*avg*	rep 1	rep 2	*avg*	*avg*
CB-T 2%	1	6.09	6.14	***6.12***	***6.07***	5.78	5.78	***5.78***	***5.79***
	2	6.13	6.20	***6.17***		5.82	5.86	***5.84***	
	3	5.93	5.95	***5.94***		5.74	5.73	***5.74***	
CB-T 1%	1	6.42	6.49	***6.46***	***6.26***	5.85	5.88	***5.87***	***5.83***
	2	6.10	6.10	***6.10***		5.92	5.92	***5.92***	
	3	6.23	6.24	***6.24***		5.71	5.71	***5.71***	
HB-1/4CFAC 1% REP 3	1	6.26	6.27	***6.27***	***6.25***	5.89	5.88	***5.89***	***5.96***
	2	6.49	6.48	***6.49***		6.15	6.16	***6.16***	
	3	5.99	5.99	***5.99***		5.84	5.84	***5.84***	
HB-1/4CFAC 1%	1	6.28	6.22	***6.25***	***6.19***	5.93	5.99	***5.96***	***5.90***
	2	6.24	6.28	***6.26***		5.82	5.88	***5.85***	
	3	6.08	6.04	***6.06***		5.89	5.90	***5.90***	

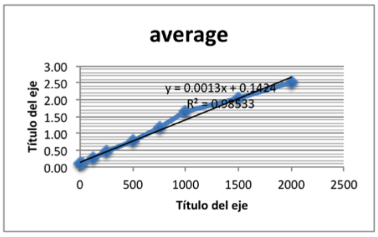
Table D.38. Raw meat R-value – Replication 4

R-value													
	sample 3 g, wave leth, 250 and 260 nm												
Frozen muscle BEFORE CHILLING							Frozen muscle AFTER CHILLING						
Sample Name	sample No.	trial No.	250 nm	260 nm	r-value	average	sample No.	trial No.	250 nm	260 nm	r-value	average	
blank(ref.)													
CB-T 2%	1	1.1	0.303	0.314	0.9650	0.9912	1	1.1	0.369	0.275	1.3418	1.3465	
		1.2	0.383	0.404	0.9480			1.2	0.377	0.279	1.3513		
	2	2.1	0.362	0.377	0.9602		2	2.1	0.324	0.262	1.2366	1.2346	
		2.2	0.358	0.368	0.9728			2.2	0.318	0.258	1.2326		
	3	3.1	0.358	0.343	1.0437		3	3.1	0.350	0.268	1.3060	1.2984	
		3.2	0.369	0.349	1.0573			3.2	0.355	0.275	1.2909		
CB-T 1%	1	1.1	0.372	0.424	0.8774	0.9646	1	1.1	0.348	0.279	1.2473	1.2518	
		1.2	0.390	0.447	0.8725			1.2	0.348	0.277	1.2563		
	2	2.1	0.397	0.359	1.1058		2	2.1	0.374	0.280	1.3357	1.3405	
		2.2	0.384	0.350	1.0971			2.2	0.374	0.278	1.3453		
	3	3.1	0.362	0.398	0.9095		3	3.1	0.375	0.291	1.2887	1.2945	
		3.2	0.383	0.414	0.9251			3.2	0.355	0.273	1.3004		
HB-1/4CFAC 1% REP 3	1	1.1	0.375	0.400	0.9375	0.9418	1	1.1	0.390	0.344	1.1337	1.1355	
		1.2	0.362	0.386	0.9378			1.2	0.381	0.335	1.1373		
	2	2.1	0.378	0.429	0.8811		2	2.1	0.397	0.406	0.9778	0.9690	
		2.2	0.371	0.428	0.8668			2.2	0.362	0.377	0.9602		
	3	3.1	0.374	0.367	1.0191		3	3.1	0.386	0.323	1.1950	1.1890	
		3.2	0.358	0.355	1.0085			3.2	0.388	0.328	1.1829		
HB-1/4CFAC 1%	1	1.1	0.379	0.431	0.8794	0.9558	1	1.1	0.382	0.378	1.0106	0.9927	
		1.2	0.382	0.416	0.9183			1.2	0.388	0.398	0.9749		
	2	2.1	0.379	0.422	0.8981		2	2.1	0.378	0.292	1.2945	1.2869	
		2.2	0.369	0.409	0.9022			2.2	0.394	0.308	1.2792		
	3	3.1	0.405	0.379	1.0686		3	3.1	0.387	0.297	1.3030	1.2925	
		3.2	0.392	0.367	1.0681			3.2	0.382	0.298	1.2819		

Table D.39. Protein solubility– Replication 4

T1 REG

[Protein] ug/ml	absorbance 1	absorbance 2	average
2000	2.525	2.503	2.53
1500	2.019	2.033	2.03
1000	1.907	1.398	1.65
750	1.174	1.128	1.15
500	0.764	0.755	0.76
250	0.439	0.441	0.44
125	0.255	0.25	0.25
25	0.114	0.119	0.12
0	0.103	0.105	0.10



CB-T 2%					initial [Protein] g/gbatter	0.04665	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	%prot solubility
19.90	min6	0.655	0.633	0.644	385.85	0.0154	33.08%
25.50	min 9	0.641	0.67	0.6555	394.69	0.0158	33.84%
28.30	min 12	0.583	0.658	0.6205	367.77	0.0147	31.53%
31.80	min 15	0.597	0.608	0.6025	353.92	0.0142	30.35%
33.80	min 18	0.601	0.608	0.6045	355.46	0.0142	30.48%
35.50	min 21	0.577	0.568	0.5725	330.85	0.0132	28.37%
36.80	min 24	0.586	0.591	0.5885	343.15	0.0137	29.42%
37.60	min27			#¡DIV/0!	#¡DIV/0!	#¡DIV/0!	#¡DIV/0!

CB-T 1%					initial [Protein] g/gbatter	0.04665	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	%prot solubility
19.90	min6	0.525	0.591	0.558	319.69	0.0128	27.41%
25.50	min 9	0.591	0.606	0.5985	350.85	0.0140	30.08%
28.30	min 12	0.55	0.576	0.563	323.54	0.0129	27.74%
31.80	min 15	0.539	0.574	0.5565	318.54	0.0127	27.31%
33.80	min 18	0.591	0.609	0.6	352.00	0.0141	30.18%
35.50	min 21	0.694	0.676	0.685	417.38	0.0167	35.79%
36.80	min 24	0.755	0.734	0.7445	463.15	0.0185	39.71%
37.60	min27	0.625	0.595	0.61	397.75	0.0159	34.10%

HB-1/4CFAC 1% REP 3					initial [Protein] g/gbatter	0.04665	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	%prot solubility
19.90	min6	0.774	0.776	0.775	537.75	0.0215	46.11%
25.50	min 9	0.744	0.741	0.7425	510.67	0.0204	43.79%
28.30	min 12	0.727	0.805	0.766	530.25	0.0212	45.46%
31.80	min 15	0.747	0.763	0.755	521.08	0.0208	44.68%
33.80	min 18	0.778	0.798	0.788	548.58	0.0219	47.04%
35.50	min 21	0.666	0.733	0.6995	474.83	0.0190	40.71%
36.80	min 24	0.908	0.949	0.9285	665.67	0.0266	57.08%
37.60	min27	0.858	0.833	0.8455	596.50	0.0239	51.15%

HB-1/4CFAC 1%					initial [Protein] g/gbatter	0.04665	
Tº	time	absorbance 1	absorbance 2	average	[Protein] ug/ml	g/gbatter	%prot solubility
19.90	min6	0.717	0.736	0.7265	494.83	0.0198	42.43%
25.50	min 9	0.752	0.751	0.7515	515.67	0.0206	44.21%
28.30	min 12	0.68	0.696	0.688	462.75	0.0185	39.68%
31.80	min 15	0.763	0.759	0.761	523.58	0.0209	44.89%
33.80	min 18	0.763	0.759	0.761	523.58	0.0209	44.89%
35.50	min 21	0.764	0.818	0.791	548.58	0.0219	47.04%
36.80	min 24	0.795	0.803	0.799	555.25	0.0222	47.61%
37.60	min27	0.81	0.789	0.7995	555.67	0.0222	47.64%

Table D.40. Torsion test CB-T 2% – Replication 4

Torsion Test

Date: / /

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC REG SODIUM	CB-T 2% min 6	1	13.14	10.5	20.79	1.46	19.50	0.87
		2	11.84	4.8	18.73	0.62		
		3	12.54	5.6	19.84	0.73		
		4	11.66	5.4	18.45	0.71		
		5	11.94	6.9	18.89	0.93		
		6	12.83	5.9	20.30	0.78		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 9	1	14.16	5.40	22.40	0.69	21.38	0.32
		2	13.34	5.00	21.10	0.64		
		3	13.3	4.90	21.04	0.62		
		4	14.06	4.20	22.24	0.51		
		5	12.71	5.50	20.11	0.72		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 12	1	16.02	6.80	25.34	0.88	23.80	0.85
		2	15.14	6.60	23.95	0.86		
		3	13.1	6.20	20.72	0.82		
		4	14.66	5.20	23.19	0.66		
		5	13.83	8.20	21.88	1.11		
		6	16.81	6.20	26.59	0.79		
		7	15.77	6.50	24.95	0.84		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 15	1	14.82	9.30	23.45	1.27	23.90	0.85
		2	13.05	6.70	20.65	0.89		
		3	14.66	6.30	23.19	0.82		
		4	15.95	5.90	25.23	0.75		
		5	16.13	5.80	25.52	0.73		
		6	16	6.2	25.31	0.79		
		7	15.15	5.70	23.97	0.73		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 18	1	13.73	6.40	21.72	0.84	23.01	0.85
		2	14.2	7.20	22.46	0.96		
		3	16.34	7.00	25.85	0.91		
		4	15.81	6.20	25.01	0.80		
		5	14.99	6.50	23.71	0.85		
		6	13.22	6.30	20.91	0.83		
		7	13.96	6.10	22.08	0.80		
		8	14.1	6.20	22.31	0.81		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 21	1	17.33	7.5	27.42	0.98	25.20	1.16
		2	15.86	10.9	25.09	1.50		
		3	14.82	10.2	23.45	1.40		
		4	15.87	7	25.11	0.91		
		5	15.44	6.8	24.43	0.89		
		6	16.68	8.2	26.39	1.09		
		7	15.49	10	24.51	1.37		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 24	1	14.99	6.2	23.71	0.80	22.78	0.98
		2	14.19	8	22.45	1.08		
		3	14.19	8	22.45	1.08		
		4	15.81	6.8	25.01	0.89		
		5	13.12	7.1	20.76	0.95		
		6	14.53	8.7	22.99	1.18		
		7	13.96	6.5	22.08	0.86		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 2% min 27	1	16.56	8.4	26.20	1.12	24.65	0.98
		2	13.61	6.3	21.53	0.83		
		3	13.88	6.7	21.96	0.89		
		4	15.84	7.6	25.06	1.00		
		5	18.03	8	28.52	1.05		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.41. Torsion test CB-T 1% – Replication 4

Torsion Test

Date: / /

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T1 Post Rigor WC LOW SODIUM	CB-T 1% min 6	1	13.41	7.4	21.21	1.00	19.50	1.18
		2	11.83	6.7	18.72	0.90		
		3	11.3	10.5	17.88	1.48		
		4	12.52	8.8	19.81	1.21		
		5	12.56	9.5	19.87	1.32		
		6			0.00	0.00		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 9	1	15.6	8.40	24.68	1.13	23.26	1.16
		2	13.04	7.60	20.63	1.03		
		3	15.21	11.90	24.06	1.65		
		4	15.25	7.80	24.13	1.04		
		5	14.09	7.90	22.29	1.06		
		6	14.32	7.50	22.65	1.00		
		7	15.39	8.70	24.35	1.17		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 12	1	15.71	11.70	24.85	1.62	25.86	1.22
		2	15.16	8.40	23.98	1.13		
		3	17.2	9.70	27.21	1.31		
		4	16.49	8.40	26.09	1.12		
		5	16.17	8.20	25.58	1.09		
		6	17.53	8.80	27.73	1.17		
		7	16.18	8.20	25.60	1.09		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 15	1	15.71	11.70	24.85	1.62	25.86	1.22
		2	15.16	8.40	23.98	1.13		
		3	17.2	9.70	27.21	1.31		
		4	16.49	8.30	26.09	1.10		
		5	16.17	8.20	25.58	1.09		
		6	17.53	8.8	27.73	1.17		
		7	16.18	8.30	25.60	1.11		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 18	1	14.18	7.70	22.43	1.03	23.28	1.14
		2	14.97	8.20	23.68	1.10		
		3	15.54	8.50	24.58	1.14		
		4	14.5	7.80	22.94	1.05		
		5	13.68	8.00	21.64	1.08		
		6	13.22	7.40	20.91	1.00		
		7	16.22	11.70	25.66	1.62		
		8	15.41	8.00	24.38	1.07		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 21	1	12.52	7.2	19.81	0.97	21.20	1.35
		2	12.67	8.2	20.04	1.12		
		3	15.24	12.2	24.11	1.70		
		4	13.51	7.5	21.37	1.01		
		5	13.67	13.67	21.63	1.93		
		6	12.56	7.8	19.87	1.06		
		7	13.64	11.8	21.58	1.65		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 24	1	14.5	7.9	22.94	1.06	24.88	1.22
		2	14.69	8.8	23.24	1.19		
		3	16	9	25.31	1.21		
		4	15.46	8.9	24.46	1.20		
		5	15.74	8.3	24.90	1.11		
		6	14.9	8.7	23.57	1.18		
		7	16.07	9.2	25.42	1.24		
		8	18.48	11.4	29.24	1.55		
		9			0.00	0.00		
		10			0.00	0.00		
	CB-T 1% min 27	1	13.64	8.1	21.58	1.10	21.16	1.11
		2	12.85	7.7	20.33	1.05		
		3	12.98	8.2	20.53	1.12		
		4	11.7	7.5	18.51	1.02		
		5	12.84	8.4	20.31	1.15		
		6	15	8.5	23.73	1.15		
		7	12.99	8.2	20.55	1.12		
		8	15.02	8.6	23.76	1.16		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.42. Torsion test HB- ¼CFAC 1% REP 3 – Replication 4

Torsion Test

Date: / /

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T5 PRE Rigor 1/4 CFC LOW R2 SODIUM	HB-1/4CFAC 1% REP 3 min 6	1	19.07	8.8	30.17	1.16	35.04	0.99
		2	20.49	8.9	32.42	1.16		
		3	19.86	7.5	31.42	0.96		
		4	23.92	8.4	37.84	1.06		
		5	27.16	7.9	42.97	0.95		
		6	21.33	6.4	33.74	0.78		
		7	23.21	7.1	36.72	0.87		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% REP 3 min 9	1	27.94	7.00	44.20	0.81	45.32	0.85
		2	32.71	8.60	51.75	1.01		
		3	35.17	8.17	55.64	0.93		
		4	29.39	6.80	46.49	0.77		
		5	22.61	6.60	35.77	0.80		
		6	25.89	7.60	40.96	0.92		
		7	24.62	6.80	38.95	0.81		
		8	30.85	6.90	48.80	0.77		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% REP 3 min 12	1	30.96	7.80	48.98	0.91	60.04	0.95
		2	40.84	9.10	64.61	1.02		
		3	39.3	8.20	62.17	0.90		
		4	41.06	8.30	64.96	0.90		
		5	33.46	8.80	52.93	1.04		
		6	38.86	8.30	61.48	0.91		
		7	41.19	8.80	65.16	0.97		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% REP 3 min 15	1	45.26	9.40	71.60	1.03	72.26	1.02
		2	43.79	9.40	69.28	1.04		
		3	45.72	9.20	72.33	0.99		
		4	44.94	9.60	71.10	1.06		
		5	48.36	9.50	76.51	1.01		
		6	41.2	8.9	65.18	0.98		
		7	51.36	9.90	81.25	1.05		
		8	44.79	9.30	70.86	1.01		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% REP 3 min 18	1	38.86	8.40	61.48	0.93	62.05	0.90
		2	40.67	8.50	64.34	0.93		
		3	40.41	8.10	63.93	0.87		
		4	34.53	8.00	54.63	0.91		
		5	37.53	8.40	59.37	0.94		
		6	42.17	8.70	66.71	0.95		
		7	37.62	8.00	59.51	0.88		
		8	41.97	7.90	66.40	0.83		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% REP 3 min 21	1	41.08	9.4	64.99	1.06	64.86	1.06
		2	37.21	8.9	58.87	1.02		
		3	38.6	8.8	61.07	0.99		
		4	42.21	9.2	66.78	1.02		
		5	46.05	9.9	72.85	1.09		
		6	41.37	10.4	65.45	1.21		
		7	39.85	9	63.04	1.01		
		8	41.6	9.7	65.81	1.10		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% REP 3 min 24	1	28.71	7.9	45.42	0.94	48.24	0.98
		2	32.55	8.2	51.49	0.95		
		3	26.38	8.3	41.73	1.02		
		4	32.94	8.2	52.11	0.95		
		5	33.85	9	53.55	1.06		
		6	28.53	7.8	45.13	0.93		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% REP 3 min 27	1	35.74	9	56.54	1.05	60.00	1.10
		2	41.05	9.9	64.94	1.14		
		3	39.21	9.8	62.03	1.14		
		4	34.35	9	54.34	1.06		
		5	41.09	9.6	65.00	1.09		
		6	37.63	9.3	59.53	1.07		
		7	37.74	9.6	59.70	1.12		
		8	36.6	9.9	57.90	1.17		
		9			0.00	0.00		
		10			0.00	0.00		

Table D.43. Torsion test HB- ¼CFAC 1%– Replication 4

Torsion Test

Date: / /

	Sample Name	Sample #	Torque(%)	Time at fracture	Stress(kpa)	Strain	Stress Avg	Strain Avg
T5 PRE Rigor 1/4 CFC LOW SODIUM	HB-1/4CFAC 1% min 6	1	12.92	4.7	20.44	0.59	24.70	0.69
		2	16.55	5.8	26.18	0.73		
		3	12.76	5.2	20.19	0.67		
		4	15.5	5.5	24.52	0.69		
		5	17.18	5.8	27.18	0.72		
		6	18.27	6.1	28.90	0.76		
		7	16.13	5.3	25.52	0.66		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 9	1	24.7	6.80	39.08	0.81	41.38	0.83
		2	27.6	7.00	43.66	0.82		
		3	19.21	6.10	30.39	0.75		
		4	28.65	7.60	45.32	0.90		
		5	29.07	7.40	45.99	0.86		
		6	29.28	7.50	46.32	0.88		
		7	24.6	6.50	38.92	0.77		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 12	1	26.29	7.20	41.59	0.86	47.87	0.91
		2	30.37	7.10	48.05	0.81		
		3	36.66	8.40	58.00	0.95		
		4	27.32	8.10	43.22	0.98		
		5	30.39	7.80	48.08	0.91		
		6	27.89	7.80	44.12	0.93		
		7	26.28	7.20	41.57	0.86		
		8	36.87	8.60	58.33	0.98		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 15	1	41.56	9.10	65.75	1.01	61.44	0.97
		2	39.21	8.50	62.03	0.94		
		3	35.68	8.50	56.45	0.97		
		4	44.38	9.40	70.21	1.03		
		5	35.68	8.50	56.45	0.97		
		6	42.86	8.5	67.80	0.91		
		7	42.49	8.90	67.22	0.97		
		8	28.84	7.70	45.62	0.91		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 18	1	40.79	9.10	64.53	1.02	55.71	0.96
		2	37.1	8.40	58.69	0.94		
		3	34.21	7.50	54.12	0.83		
		4	37.94	9.00	60.02	1.03		
		5	33.78	7.80	53.44	0.88		
		6	36.14	8.50	57.17	0.97		
		7	41.1	9.10	65.02	1.02		
		8	20.68	7.70	32.72	0.98		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 21	1	31.54	8.7	49.90	1.04	52.44	1.05
		2	32.95	9.1	52.13	1.08		
		3	36.87	9.4	58.33	1.10		
		4	35.36	9.3	55.94	1.09		
		5	33.5	9.2	53.00	1.09		
		6	32.63	8.6	51.62	1.01		
		7	32.31	8.5	51.11	1.00		
		8	30	8.2	47.46	0.97		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 24	1	35.93	9.8	56.84	1.16	56.55	1.11
		2	42.18	9	66.73	0.99		
		3	35.51	9.7	56.18	1.15		
		4	34.15	10	54.03	1.21		
		5	29.46	8.4	46.61	1.01		
		6	34.07	9.1	53.90	1.08		
		7	36.45	9.7	57.66	1.14		
		8	38.2	9.7	60.43	1.13		
		9			0.00	0.00		
		10			0.00	0.00		
	HB-1/4CFAC 1% min 27	1	35.73	8.3	56.52	0.94	58.58	0.97
		2	38.31	8.8	60.61	0.99		
		3	36.99	8.8	58.52	1.01		
		4	31.33	7.8	49.56	0.90		
		5	38.22	8.5	60.46	0.95		
		6	41.6	9.2	65.81	1.03		
		7			0.00	0.00		
		8			0.00	0.00		
		9			0.00	0.00		
		10			0.00	0.00		

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