

RAPID ANALYTICAL METHODS FOR THE DETERMINATION OF  
FAT AND MOISTURE CONTENT OF  
GROUND MEATS

by

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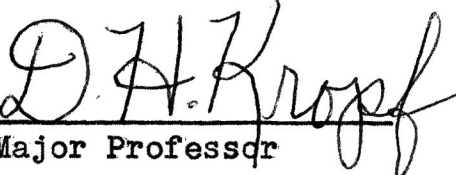
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## INTRODUCTION

The determination of the Moisture and Fat Content of ground meat and meat products has utmost importance to the meat packing industry and the consumer, who is often represented by the Governmental Regulatory Agencies. Moisture, protein, and fat are important components of meat, fat and moisture being relatively less expensive components. Certain fat and moisture levels are desirable in ground meats and prepared meat products. Water is usually added as ice to facilitate grinding and to reduce temperature. It is also added to processed meats and meat products to impart the desired consistency and texture, to dissolve curing ingredients, and to minimize shrinkage in cooked and smoked meat items.

Although the consumer wants his ground meat palatable, it should not be unduly wasteful. The meat packing industry operates at an extremely small margin of profit, and is often forced to add more fat and water as they are less expensive than muscle. The Government, representing the consumer, imposes legal limitations to protect consumer interests. Some meat packing houses, however, practice accurate and economical product formulation resulting in a uniform reliable product for the consumer with maximum profit and quality. The Meat Industry cannot afford losses entailed by substandard or extra-legal batches of product which can be avoided by careful quality control.

To control product composition, the composition of the raw materials used must be known with reasonable accuracy early enough in production to permit adjustments. Formulations developed by assuming an average level for a specific raw material often differ widely from specifications.

Existing official Methods of Analysis for Fat and Moisture content in Meats are not suitable for active quality control by the Meat Packers and for preventative action by Government Inspectors with one main disadvantage being the long time interval before results are known. The importance of the problem has led to development of many rapid methods for fat and moisture analysis.

The work reported in this thesis was undertaken to:

1. Compare the official methods as specified by the Association of Official Analytical Chemists, formerly Association of Agricultural Chemists, hereafter designated as the A.O.A.C. method; Steinlite Electronic Fat Tester; two modified Babcock Methods of fat analysis on ground meat samples of three fat levels and on pork sausage samples.
2. Compare the A.O.A.C. and Moisture Determination balance methods of moisture determination on ground meat samples of three moisture levels and on pork sausage.
3. Determine the effect of salt on Steinlite Electronic Fat Tester results.

## REVIEW OF LITERATURE

### Methods for Determination of Moisture Content

The determination of water is one of the most common methods of analysis. Water is present in organic products as a combined constituent, as a contaminant, or as a diluent or "added" water [Willits (1951), Wierbicki et al. (1958)], and many materials pick up water from the air. Moisture may influence the activity of some ingredients and many compounds, other than meat, are sold on a "dry" basis. Hence the determination of water or moisture content is necessary and must precede other determinations on a sample (Stillman, 1950).

The most common methods for determining water or moisture can be classified into the following groups; namely oven drying, distillation, titration, electrical measurement of water vapor with hygroscopic film, and others.

### Thermal Dehydration

Oven drying or thermal drying is the simplest and probably the oldest method of moisture analysis. Even today, a common concept of moisture analysis is that implied by an old 1885 procedure of the A.O.A.C. which specified moisture as the loss in weight occurring when a substance was heated at 98°C to 100°C (Willits, 1951). This is the most time consuming method and yet forms the standard for most other moisture methods. The expected changes during the heating of a moist organic substance are volatilization of water as moisture, volatilization of other absorbed material, and volatilization of the gaseous products

formed by non-reversible decomposition reactions which go on at all temperatures at varying rates.

Nelson and Hulett (1920) found that when an organic substance was heated at constant temperature, the amount of water liberated from that existing as an external phase, was dependent upon temperature and its rate of moisture removal, which is rapid at first, but in time ceases. Their isotherms indicated that some water remained after successively increased temperature probably due to successive thinner layers of water or some other physical phenomenon. Porter and Willis (1944) using potato starch, obtained similar drying isotherms and estimated the end value of drying and the beginning of weight loss due to the decomposition of the sample. Further studies by Sair and Fetzer (1944) and Makower et al. (1946) showed that values of "true moisture" could be reproducible by establishing conditions of time and temperature which did not denature the sample.

During oven drying, the moisture of interest is that occurring principally as an external phase and that occurring as one or more molecular layers plus liquid water (Willits, 1951). Ideal conditions for thermal drying as stated by Willits were:

1. Using diminished pressure to minimize time of diffusion of deep-seated moisture.
2. Using dessicated air to sweep out water vapor from drying chamber.
3. Heating the sample at temperature lower than that at which the rate of decomposition becomes appreciable.

Some of the sources of error in thermal drying were reviewed by Reith et al. (1948) as stated by Willits (1951).

1. Nonwater components. In thermal drying, errors will be introduced if the material being dried contains any substances in addition to water which have an appreciable vapor pressure under the conditions of the drying causing an additional loss in weight of the sample resulting in "high moisture" values.

2. Chemically bonded water. Small quantities of water may be lost through chemical reaction induced by heat as in the case of dextrin formation, inversion of disaccharides, or hydrolysis of proteins.

3. Nonwater Solvents. Often in the case of preparative organic substances which have been crystallized from such solvents as acetone or alcohol, moisture values are too low as indicated by elemental analyses. The "incomplete drying" is due to substances held throughout the thermal process.

4. Autoxidation. Chemical changes cause an apparent low moisture due to increased weight of sample by autoxidation, especially in fats and oils.

5. Decomposition. This occurs when the temperature of drying is sufficient to cause thermal decomposition of the substance and the products of this decomposition are volatile resulting in "high moisture" values.

Willits (1951) pointed out additional sources of error:

1. Slowness in establishing equilibrium between the vapor pressure of the water of the solid and that of the atmosphere may cause a slow rate of volatilization of the water

resulting in incomplete drying, as in the case of lactose hydrate or starch.

2. Crust formation. The formation of a water impervious crust causes a nearly complete stoppage of evaporation of the remaining moisture.

3. The physical structure of plant or animal tissue. Both types of tissue often contain as high as 60 to 90% moisture. The removal of moisture from the cells, vacuoles, and tubes of these tissues presents separate problems. Cell moisture must diffuse through the cell wall before it can be volatilized. The moisture must leave the surface of the cells by diffusion and this can be slow in thick materials. Furthermore, as the cells lose water and the cell fluid becomes more concentrated, there is a lowering of the vapor pressure of the residual water. To drive the last traces of moisture out of the cells at a reasonable rate, the temperature must be increased, and this often makes the cells less permeable to water and also tends to seal the tubes in the tissue making diffusion of deep seated water vapor very slow.

4. Sampling is a common source of error in moisture analyses, particularly for substances with high moisture content. These samples usually have water vapor pressures much higher than the ambient air and therefore undergo rapid changes. A material having a water content of 90% or more with an error of sampling, which accounts for only a one per cent error in moisture, can cause a 10% error in the non-volatile constituents reported on a moisture-free basis.



Willits suggested that most of these errors can readily be avoided, with the possible exception of those caused by non water volatile constituents. Three methods that tend to minimize errors due to non water volatile constituents are collection of the volatilized water, using an absorbent specific to water, and the indirect methods of Makower and Porter (1946).

Loss of water through chemical reaction can best be prevented by drying the sample at low temperatures until the bulk of the water has been removed and the possibility of the reaction reduced to a minimum. The substance can then be dried at the desired elevated temperature.

To prevent errors from substances previously treated with such solvents as alcohol or acetone, the best remedy is to humidify the sample, in which process the solvent is replaced by water and then this is removed by the accepted thermal method.

To limit errors from oxidative changes, an inert gas (oxygen free) such as nitrogen or carbon dioxide is used in the thermal drying chamber.

For substances that undergo thermal decomposition, it is possible to determine the critical temperature at which decomposition occurs and to use temperatures in a range below this value for thermal drying.

Where there is slowness in establishing equilibria between the vapor pressure of the water of the solid and that of the atmosphere, this error can be avoided by drying for a longer time, using a higher drying temperature, or both.

The formation of an impervious crust can be avoided by use of sand dishes to increase the exposed surface or by top drying at moderate temperatures under infra-red heat lamps.

Errors due to physical structure can often be avoided by fine grinding to diminish the distance through which the water vapor must diffuse, and by using multiple stage drying, so that most of the moisture can be removed at temperatures at which the cell walls remain permeable to water. Sampling errors need further studies and this error is inherent in all moisture determination methods as noted by Willits.

The kind of oven to be used will depend on type of moisture, time of drying, and physical structure of the sample. For loosely held liquid water, any type of drying is satisfactory. For surface water and if time is a factor, high temperatures below thermal decomposition are employed in a forced air oven. Drying is usually four times as fast in mechanical convection ovens as it is in gravity convection ovens and greater uniformity of temperature is maintained (Willits, 1951). When the moisture is deep seated and has to diffuse through capillaries, a decided advantage may be gained through the use of vacuum drying.

The determination of moisture by distillation was described by Hoffman in 1902. The procedure measures actual water (Fetzer, 1951). Hoffman used turpentine and toluene as distilling liquids while Brown and Duvel (1907) applied the distillation on grain using a mineral oil as a distilling liquid. Their modification reduced the test time to 30 minutes. The method

was applied on fats, oils and soaps using xylene or benzene (Marcusson, 1905). Schwalbe (1908) advanced the views of high boiling point distilling liquid on dense materials. The development of the Dean and Stark (1920) "distilling receiver tubes" permitted use of low boiling point liquids with continuous refluxing and a separation of water. The Bidwell and Sterling (1925) "traps" improved the design for precise work. Norman (1925) and Yamada (1927) drew attention to "still heads" and built-in reflux condensers. Dedlow and Smith (1926) found that xylene distillation caused decomposition when applied to meat extracts and modified the method by conducting the distillation with xylene under a vacuum. Rice (1929) introduced the use of the filter cel in distillation flask and this useful technique was further developed by Fetzer et al. (1935) to apply to viscous materials. Trusler (1940) reported the use of benzene, toluene, and xylene in determination of moisture in soaps. Comprehensive research was reported by Evans and Fetzer (1941) and Cleland and Fetzer (1941) on the moisture determination in sugar products, which often causes trouble in oven drying.

The Sair-Fetzer method of distillation which gave "true moisture" (1942) is the official method for moisture in cereals. Use of carbon tetrachloride as distilling liquid was reported by Alexander (1936) and Marcusson (1948). Rogers et al. (1910) made contributions to the technique of using a volatile liquid heavier than water.

The apparatus in use today vary in design, particularly the design of the moisture receivers or "traps." The designs have been so widely accepted that they bear the inventor's name. For distilling liquids lighter than water the moisture receivers are:

1. Brown-Duvel: No provision for refluxing
2. Dean-Stark: (for multiple distillation and has "trap" which is removed and weighed)
3. Bidwell-Sterling: has a better "trap" allowing a slow return of the distilled liquid
4. Cleland and Fetzer: increased capacity of the "trap"

For heavier liquids, three traps are listed:

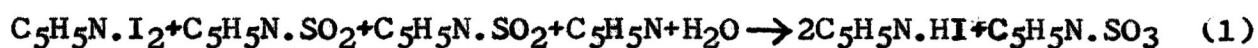
1. Hercules Trap
2. Bailey Trap
3. Langeland - Pratt Trap

For distilling oils, the moisture receiver is a ASTM (American Society Testing Materials) Clevenger Trap.

To analyze a sample by this method, the choice of the distilling liquid or boiling point is important. Toluene (b. pt.  $110^{\circ}$  to  $112^{\circ}\text{C}$ ) is high enough for most materials (Willits, 1951). If the material is heat sensitive, benzene or mixtures of benzene and toluene should be used (Willits, 1951). A blank determination must be run on the distilling liquid and the sample size should be chosen so that the amount of collected water falls within 3.5 to 5.0 ml. range, thus approaching the maximum holding capacity of the trap and resulting in greater precision.

### The Karl Fischer Reagent Titration

The Karl Fischer Reagent Titration method is the most widely used chemical method for determining moisture in many more types of materials than any other method. It was first described in 1935 by Karl Fischer. Either a visual or an electrometric end point may be employed. The former requires only simple apparatus, namely a buret and a long necked flask and is sensitive to less than 0.5 mg of water. The electrometric method requires a desiccant protected-closed system and is sensitive to about 0.2 mg of water (Mitchell, 1951). The "dead stop" end point employing a direct titration procedure appears to be the most convenient electrometric technique (Carter and Williamson, 1945). Fischer reagent consists of iodine, sulfur dioxide, pyridine and methanol. The overall process involves the two step reaction as stated by Smith et al. (1939):



and



Numerous variations have been proposed and bromine has sometimes been used in place of iodine (McComan et al., 1949) (Johansson, 1947). Organic substances which interfere in the direct titration for water include carbonyl compounds, mercaptans, diacyl peroxides, thioacids and hydrazines. There are methods to eliminate these interferences (Mitchell, 1940). Inorganic compounds which interfere include metal oxides, hydroxides, carbonates, bicarbonates, chromates, dichromates, borates and

sulfides. Often the interfering reactions are quantitative. Several methods based on prior distillation or extractions with water have been proposed and are becoming increasingly important. Reliable methods have been devised for the determination of water in petroleum products, oils, fats, and foodstuffs like soybean (McComb, 1960). In most cases, the Fischer reagent results were higher than the accepted procedures. Possibly this titration includes water of hydration (Schroeder and Nair, 1948). Experiments to date indicate that the method can result in a time-saving and reliable procedure in all studies involving the determination of water.

#### Electrical and Other Methods

Electrical methods have been tried. Microwaves are electromagnetic radiations which interact with materials such as water to sense the moisture content of the product directly, instantly and continuously during production. No sampling is necessary and the test sample is not lost. An accuracy of  $\pm 0.2\%$  moisture is claimed and can gauge moisture levels from 1% to 99% (Microwave Instruments Co., 1966).

Dunmore Hygrometers have been tried on solid foods.

Cryoscopy is widely used in the dairy industry to determine added water by observing a change of the freezing point (Standard Methods, A.P.H.A. 1960).

Nuclear Magnetic Resonance Spectrometers are being developed and have proven successful on static methods of meat

processing (King, 1966). The Varian PA-7 Process Analyzer is one of the commercial Nuclear Magnetic Resonance analyzers on the market. The manufacturers have claimed that the instrument has been used with success to determine moisture in wheat, sugar, corn, wool, soap, etc., and that it was highly sensitive, and that it could take single measurements in thirty seconds with 1% measurement accuracy. It was also claimed that it was non-destructive to the sample and that the results could be read out directly in % by weight (Varian Associates, 1966). There isn't enough evidence yet to support this claim for meat. Lustig (1966) has recently reviewed literature on Nuclear Magnetic Resonance (NMR) spectrometry, and NMR analysis of meat composition was discussed by King (1966). He stated that the new technique of high Nuclear Magnetic Resolution had the ability to detect and separately indicate the amount of fat and water in mixtures. Again, not enough data has been available to support this technique but he explained that although the initial investment would be large, its advantages and low cost in time were enough cause for considering it. Recent developments, he reported, largely overcame the disadvantages of limited sample size and instability in previous instrumentation. The technique was suitable for static laboratory measurements, and that it was being adapted to continuous, accurate flow stream measurements of fat and water content for continuously indicating and recording both the amount of fat and water in meat products on a production line. The basis for the operation as outlined by King (1966) was the phenomenon of Nuclear Magnetic Resonance wherein

the nucleus of the atom in a static magnetic field strongly interacted with an applied radio frequency electromagnetic field only at a particular (resonant) frequency. Instrumentation designed to detect the interaction could indicate not only the presence of nuclei of a given atomic specie but also the quantity of the nuclei in a defined region. For a constant magnetic field, the nuclei of different elements resonate at different frequencies, and conversely, for an electromagnetic field of constant frequency the magnitude of static magnetic field required to produce the strong interaction was different for the nuclei of each element. Thus, the presence of different elements in a sample could be selectively detected (King, 1966). King further explained that with high resolution NMR techniques, the analysis of the structure of the molecules allowed the selective detection ("chemical shift") of the concentration of different compounds in a sample that contained the same type of nuclei, and cited the hydrogen nucleus (proton) as an example of the proton which could be separately detected in both water and fats.

Steinlite Electronic Moisture Tester Model 300 LSC is claimed to be the most economical, dependable and simplest electronic equipment. A wide range of materials can be tested in less than a minute and 300 tests can be performed on a single Steinlite in a day. The sample is not denatured and the instrument consumes no more electricity than a 30-watt light bulb.

Moisture determination balances are marketed under various trade names. They operate on the principle of thermal drying effected by an infra-red lamp held over the sample in a pan.



For the most efficient operation, it is necessary to know the characteristic of the most frequently used materials and prepare the drying curves of the specific material.

To prepare a drying curve (or isotherm), a 10 gram sample is weighed on the moisture determination balance itself and the percent moisture loss is recorded at one minute intervals. When the percent moisture loss values are plotted against time, the length of time required for complete drying is determined by the plateau of the curve. Several drying curves should be run at several heater settings and for the most efficient operation, a heater setting just low enough to prevent scorching, and a timer setting just at the point where the drying curve reaches its highest plateau should be used.

Percent Moisture loss is based on the following equation:

$$\text{Moisture Loss} = \frac{\text{Wet Sample Weight} - \text{Dry Sample Weight}}{\text{Wet Sample Weight}}$$

$$\text{Percent Moisture Loss} = \frac{\text{Wet Sample Weight} - \text{Dry Sample Weight}}{\text{Wet Sample Weight}} \times 100$$

The accuracy of the final percent moisture value is dependent upon the accuracy with which the initial 10 gram sample is weighed.

Accuracies of within  $\pm 5\%$  have been claimed and the results compared closely with the official oven drying methods.

The inherent error in this method is that complete drying cannot be effected in equilibrium with water vapor in the atmosphere. The spattering of the fats limits the amount of

heat which can apply so that a meat sample cannot be dried any faster without inaccuracies.

Everson et al. (1955) investigated the possibility of combining the principles of two methods into one method for both.

A distillation method employing an azeotropic mixture with capryl alcohol was applied to meat samples and the moisture in the sample distilled, collected and measured volumetrically. A 15. gram meat sample was used and results were obtained in ten to fifteen minutes. The percentage of moisture was calculated as follows:

$$\text{Moisture \%} = \frac{\text{Volume of Water Collected} \times 100}{15}$$

The electrical capacitance of the residual alcohol-fat solution was measured in the Steinlite Electronic Fat Tester and the fat content read from a previously prepared chart converting capacitance readings to fat content. A solvent mixture of capryl alcohol (2-Octanol) and Octyl alcohol (1-Octanol) was used.

The results of the combined methods were reproducible and compared favorably with official methods. The total procedure required 20 to 30 minutes. The limiting factors were the great effect of temperature of mixture and the fact that addition of one drop of water to the solvent would cause 1% error.

#### Methods for Fat

##### Ether Extract

The determination of the fat content in meats by ether extraction was first recorded by the Association of Official

Agricultural Chemists (1901); where the meat sample was first digested with pepsin, treated with alcohol to remove water, and then with ether in a continuous extractor. Wiley (1907) stated that some fats have substances insoluble in ether and Kelley (1955) reported that there are also minute quantities of bodies, not fats, in foods soluble in ether which are included in the ether extract. Solvent extraction of the wet material following acidification was reported by Bixby et al. (1954) and Trunin (1941) and following acid hydrolysis by Windham (1953). For wet ether extraction, Bixby et al. (1954) used modified Roose-Gottlieb and Mojonnier Methods (Rohrig, 1905, and Mojonnier et al., 1925), and compared it to the dry ethyl ether extraction method on fresh liver samples. The study revealed that Mojonnier flasks could be successfully applied to the determination of crude fat in about two hours as compared to twenty-four hours with dry ether extraction method. The liver fat values by Mojonnier extraction were consistently from 1.1 to 2.8% higher than values obtained by dry ether extraction, but dry extraction employing a solvent mixture of ethyl ether, petroleum ether, and ethyl alcohol gave values that approximated those obtained by the Mojonnier extraction. Table A illustrates some of the results obtained:

Table A

| FAT FOUND IN FRESH LIVER, %. |            |             |               |
|------------------------------|------------|-------------|---------------|
| Sample No.                   | Mojonnier  | Ethyl Ether | Mixed Solvent |
| 1                            | 5.6        | 3.5         | 5.5           |
| 2                            | 6.3        | 4.5         | 6.5           |
| 3                            | 5.4        | 3.8         | 5.6           |
| 4                            | 5.4        | 3.4         | 5.3           |
| 5                            | 4.8        | 2.6         | 5.2           |
| 6                            | 7.1        | 5.4         | 7.4           |
| 7                            | 6.6        | 5.1         | 6.7           |
| 8                            | 6.5        | 5.2         | 7.2           |
| 9                            | 6.1        | 4.5         | 6.3           |
| 10                           | 4.4        | 2.8         | 4.9           |
| 11                           | 4.3        | 2.7         | 4.8           |
| 12                           | 4.1        | 2.5         | 4.5           |
| 13                           | <u>4.3</u> | <u>2.7</u>  | <u>4.8</u>    |
| Average                      | 5.5        | 3.7         | 5.7           |

In their discussion, these workers indicated that in the drying of the homogenate for dry extraction, some of the fat may be made inaccessible to ethyl ether. The higher fat values obtained with a mixed solvent could be explained on the basis that alcohol aided complete extraction by permitting ether to pass through a water barrier which could exist as residual water in sample. They also indicated that alcohol might be effective in releasing ether soluble materials that are in combination with proteins

or other substances. It was further reported by Budde (1952) that some Mojonier wet acid hydrolysis extract materials were not soluble in dry ether extract. Although the wet ether extraction methods are relatively shorter than the dry ether extraction methods, they require greater technical skill with many more man-hours of laboratory work (Salwin et al., 1955).

The widely accepted laboratory method today for the determination of crude fat in meat and meat products is a dry ether extraction method as described by the A.O.A.C. (1965). It involves weighing three or four grams of ground meat sample into thimbles containing small amounts of sand or asbestos and drying in ovens for six hours at 100 - 102°C or 1.5 hours at 125°C. The dried sample is extracted with anhydrous ether or petroleum ether for 14 - 16 hours. The extracted sample is dried for 30 minutes at 100°C, cooled and weighed, and the loss in weight reported as Ether Extract or Crude Fat. Two kinds of apparatus are commonly used for continuous ether extraction. The Goldfish apparatus is a faster extractor and a pair of results from one sample can be obtained by drying the residue and the ether extract. The manufactures have recently claimed that the latest model can give results in two to four hours and can be used in any location without a hood. The Soxhlet Extractor should be used in the hood and requires 14 to 18 hours and would be preferred in determinations involving many samples. Bixby et al. (1954) compared results obtained by

using the Goldfisch and Soxhlet techniques (Table B) and found that crude fat values obtained by using the Soxhlet technique for dry ether extraction were slightly higher than those obtained by the Goldfisch technique but less than the Majonnier.

Table B

| Sample | CRUDE FAT % IN LIVER |           |         |
|--------|----------------------|-----------|---------|
|        | Mojonnier            | Goldfisch | Soxhlet |
| 1      | 5.2                  | 2.7       | 3.1     |
| 2      | 5.8                  | 2.9       | 3.3     |
| 3      | 5.2                  | 2.7       | 3.1     |
| 4      | 6.4                  | 3.9       | 3.1     |
| 5      | 6.3                  | 3.8       | 4.6     |
| 6      | 6.1                  | 3.4       | 4.5     |

Babcock Method

The Babcock method of determining fat content in milk and milk products is widely used in the dairy industry. Sulphuric acid when added to milk, coagulates casein, then dissolves it to free fat globules which unite and form a layer over the surface of the sulphuric acid-milk mixture (Wilster, 1950). Centrifuging favors further separation of fat from the mixture.

The Babcock method has undergone modification over the years usually involving the composition of the reagents used. Copeland (1953) digested the meat with a modified Minnesota reagent as suggested by American Public Health Association (1953), and measured the volume of the separated fat in a Babcock cream bottle. Oesting and Kaufman (1945) liberated

fat from an emulsified meat sample using acetic and sulfuric acids in a Babcock milk test bottle. Talbot (1949) used sulfuric acid and amyl alcohol in a butyrometer. The accuracy of the Babcock test compared to the official method has been studied by Kelley et al. (1954) who found that the Modified Babcock analysis using acetic acid and sulfuric acid compared well with the A.O.A.C. method when the meat was ground and mixed five times. Seasoning in pork sausage interfered with the results. Salwin et al. (1955) compared a modified procedure using a perchloric-acetic acid mixture with the A.O.A.C. methods and his results agreed closely with those of the A.O.A.C. method on a wide range of meats and meat products. Windham compared the modified Babcock using sulfuric acid and centrifuging; the Babcock modification using perchloric-acetic acid mixture; and the Steinlite Method to the A.O.A.C. Method and obtained results which agreed within  $1\frac{1}{2}\%$  in all three. Recently, a modified Babcock procedure for rapid determination of fat in meats using hot Dimethyl Sulfoxide and concentrated Hydrochloric acid compared closely with the Mojonnier Method (Whalen, 1966), and the mean difference in results by the two methods was 0.5% fat. The technique was simpler and about five minutes shorter.

#### Steinlite Electronic Fat Tester

The Steinlite Electronic Fat Tester has been developed to measure the oil content of soy beans. The fat in the sample is extracted by the Steinlite Solvent by mixing in a blender.

The electrical capacitance of the filtered solvent-fat solution is measured in the Steinlite Fat Tester cell and the readings obtained are converted into fat values using a previously prepared chart converting capacitance readings to percent fat content. Furgal (1954) obtained results comparable to A.O.A.C. methods in twenty to thirty minutes for each sample with any meat. There was no significant difference in the accuracy of the two methods. He also found that the Steinlite Fat Tester had a standard error of only  $\pm 1.92\%$  while the A.O.A.C. Method had an error of  $\pm 3.2\%$ . It was also indicated in this study that curing salts may have an effect on the readings by the Steinlite. Everson et al. (1955) evaluated the technique and obtained results with a variation greater than that obtained by the A.O.A.C. Method, but the maximum difference between methods was 3% in the range of 15-40% fat. The accuracy of the Steinlite was limited primarily by the extraction procedure and temperature reading as noted by Everson et al. (1955).

Herty and Harris (1930 ) measured the specific gravity of the fat solvent extract. An empirical formula was devised to relate specific gravity to fat content. Kraybill et al. (1953) have summarized this early work. A table of specific gravities of different mammalian fat is given by Kirschenbauer (1960). "The research of Honeywell is aimed at eliminating measurements of volume, weight and temperature to make the technique work faster as its main advantage is speed. The limitations of the method are foreign ingredients and frozen moisture". (Whitehead, 1966)



The determination of fat content by gamma ray penetration has been accomplished by the Anyl Ray Machine (1961). Thirteen pounds of ground meat are packed into a special container, tamped to remove air and placed under an X-ray tube to measure the penetration of the gamma rays. The amount of penetration is supposedly proportional to percent fat. It is claimed that this is a simple technique permitting lean determinations in three seconds and requiring seven minutes for fat analysis. The sample is large enough and is not destroyed, but returned to the batch. The cost per analysis for 60 analyses per day was quoted at \$ .80 in the first year and \$ .64 in the later years (Anyl Ray Corporation, 1965). No technical information is presented to substantiate their claims regarding accuracy.

The "juice extraction method" was described by Goss (1965). "Accurate fat content determinations" were claimed to be made by compressing a ground meat sample between two flat electrodes at a fixed voltage to heat and expel the juices. When the meat becomes so dry that its resistance reaches a high value, the current falls to near zero and the heating stops. The volume of the fat layer is a predictable function of total fat. Fat determinations are effected in two to three minutes with accuracies of  $\pm 1\frac{1}{2}\%$  using a sample of 15 - 25 grams. The "Hobart Fat Tester" seems to operate on this principle but no information is available regarding its accuracy. Other methods in the literature include refractive index measurements for fat and ultrasonic methods.

Miscellaneous and Simultaneous Procedures

Wistreich et al. (1960) reported a rapid method for moisture and fat in biological materials. The paper described a simultaneous extraction of moisture and fat from meats using a special apparatus. The azeotrope-forming fat solvents used were toluene or tetrachloro-ethylene. After distilling for two hours, the volume of water it received was read and the residue in the flask weighed after drying. Their calculations were as follows:

$$\frac{\text{Moisture reading (ml)} \times 100}{\text{Sample weight (grams)}} = \% \text{ Moisture}$$

$$\frac{\text{Residue weight (grams)} \times 100}{\text{Sample weight (grams)}} = \% \text{ Residue}$$

$$100 - (\% \text{ Moisture} + \% \text{ Residue}) = \% \text{ Fat}$$

The results were obtained in three hours and they (Table C) compared "favorably" with those obtained by official methods.

Table C

COMPARISON OF RESULTS OBTAINED BY  
NEW METHOD WITH OFFICIAL METHODS

| <u>Product</u> | <u>Moisture %</u> |                 | <u>Fat %</u> |                |
|----------------|-------------------|-----------------|--------------|----------------|
|                | <u>New</u>        | <u>Air Oven</u> | <u>New</u>   | <u>Soxhlet</u> |
| Bacon          | 22.4              | 22.8            | 66.9         | 66.4           |
|                | 23.4              | 22.3            | 66.6         | 65.9           |
|                | 28.5              | 28.0            | 60.0         | 60.1           |
| Pork Skin      | 56.0              | 52.0            | 10.8         | 9.0            |
| Pork Muscle    | 73.5              | 73.2            | 5.9          | 6.1            |
| Ground Meat    | 53.5              | 52.5            | 31.6         | 31.9           |
| Sausage        | 51.0              | 51.2            | 27.5         | 27.2           |

The results obtained by the new method were comparable but slightly higher than the official methods and it was suggested probably there was no case hardening in the new method.

Davis et al. (1966) developed a rapid approximate analytical method for simultaneous determination of moisture and fat in meat and meat products. The apparatus consisted of an extraction apparatus and distillation receiver and a micro-vacuum oven was used to aid dessication. Reliable results for a sample were obtained by this method within 2 to 2½ hours over a wide range of sample selected to cover the moisture and fat content normally encountered. Statistical analysis revealed that this rapid method and the conventional method had high repeatability for duplicate determinations, and that there was a significant difference between fat and moisture values determined by the two methods. Again, the moisture values were higher than the official methods.

### Sampling

Sampling is important in any experimental study. Quality control is widely used to maintain uniformity in manufactured products. The raw materials which go into a product vary considerably in chemical composition of their constituents, and since meat is a non-homogeneous solid material, sampling procedures will have an effect on the composition of the final product. A sample consists of a small collection from a population about which we wish information. Facts learned about the sample examined will be used to make correct

inferences about the population (Snedecor, 1956). If there were no variations, any one sample would give the correct information about the population. The twin problems of sampling are to design and conduct the sampling so that the sample examined shall be representative of the population; and having studied the sample, correct inferences can be made about the sampled population with the most reliable and efficient procedures available for analyzing and interpreting the data as stated by Snedecor (1956) and Fryer (1965).

In any analytical procedure, reliable results can be obtained if a representative sample is examined. The results can be reproducible if the described technique is closely followed (Landmann, 1965). Kelley et al. (1954) presented data to support his contention that preparation of samples and sampling techniques had a decided bearing on the correlation between the different methods of analysis and the official method. Variations in results on the chemical analyses of ground meats and meat products may not only be due to variations in the chemical composition of the materials and determination methods but also may be largely due to difficulty in obtaining a representative sample.

#### Rapid Methods

In the meat packing industry, there is increasing need for simple, rapid and reasonably accurate analytical methods for fat and moisture content of meat and meat products so as to maintain control of product quality, assure compliance with regulatory restrictions, and provide a basis for monetary evaluation

of raw materials and formulation alternatives.

The official methods, sometimes called conventional methods, are not suitable for active quality control. In recent years, many investigators have developed more rapid methods for fat content in meat as the cost of the raw materials depends largely on the lean-to-fat ratio. The methods of rapid fat determination can be categorized into:

(a) Direct methods which include methods in which the fat is chemically or physically separated from the meat and then analyzed by volume or weight.

(b) Indirect methods in which the amount of fat is measured by some other characteristics of the meat which bear a relationship to the fat content (Whitehead, 1962).

Many methods are available today, the lengthy conventional methods and the rapid methods for the determination of moisture and fat content in ground meats. The indirect non-chemical methods are receiving greater attention coupled with the sophistication and publicity involved. Some of the chemical methods reviewed are giving promise of becoming rapid methods. The need for rapid methods has been outlined and an ideal rapid method should incorporate the following features:

1. The method should be rapid so that the test could be completed in half an hour or less.
2. The method should be simple enough to be carried out by non-technical personnel after a brief training period.
3. The method should permit in-plant operation.

4. The method should be reasonably accurate.
5. The method must be suitable for any meat product.
6. The method must be useful with any representative sample, and over a wide range of composition.
7. The method should not be too costly in terms of initial investment, materials per test and operator's time.

Little technical information is available regarding results of some of these methods as compared to the official method of analysis for fat and moisture. This is especially true for the Whalen Modification of the Babcock Method and for use of moisture determination balances, such as the Ohaus Moisture Determination Balance. Therefore, these methods were checked. Little information seems available regarding method of sample preparation for analysis. This seems important since homogenizers are readily available to perform a more thorough mixing, blending and cutting of sample.

## METHODS AND PROCEDURES

### Preparation of Samples

Fresh beef (shank meat) was obtained from the University Meat Laboratory. Different amounts of beef fat trimmings were added to the lean meat to obtain three fat levels of the raw material, namely low (about 15%), medium (about 20%), and high (about 25%) fat levels. The meat was ground three times in a large meat grinder using 1/8" plate, mixing thoroughly after each grinding.

Each batch was divided into two portions, A and B. The A sample was homogenized using a Waring blender and further mixing by hand; the B sample received no further treatment.

Special samples were prepared from the raw material of medium fat level by adding 3% NaCl prior to the grinding. This sample was used to test the effect of added salt on Steinlite Fat Tester results.

The meat samples were packaged in air tight "Whirlpak" bags, labelled, frozen in a blast freezer at  $-10^{\circ}\text{F}$ , and stored at  $0^{\circ}\text{F}$  until used.

For Pork Sausage, two pound samples of fresh seasoned pork sausage were obtained on the day of the test. The seasoning consisted of two pounds salt, four ounces black pepper and four ounces rubbed sage per 100 lbs. meat. Each lot was thoroughly mixed by hand and stored in water tight glass jars at  $32^{\circ}\text{F}$  until analysis.

#### Moisture Content Determinations

One method of moisture analysis consisted of oven drying using a forced circulation oven at  $100 - 102^{\circ}\text{C}$  as outlined in "Official Methods of Analysis" of the Association of Analytical (formerly Agricultural) Chemists, 10th edition, 1965, hereafter designated A.O.A.C. (1). The only modification here involved the use of paper thimbles in place of crucibles.

A second method of moisture analysis used was drying as above but using uncovered crucibles and hereafter referred to as A.O.A.C. (2).

Sample size for both A.O.A.C. (1) and A.O.A.C. (2) consisted of four to six grams.

The third method of moisture analysis utilized the Moisture Determination Balance (OHAUS). Ten grams of meat sample were rapidly and accurately weighed and placed on the Moisture Determination Balance. The heater unit was positioned at  $1\frac{1}{4}$  inches above the sample container, the heater control set at 60 watts, and the timer set at 40 minutes. Moisture loss was directly read from the scale, to the nearest 0.1% when the timer sounded the bell.

Prior to use of the Moisture Determination Balance, drying curves were run in order to determine proper conditions for this test. Several meat samples were run at different heater settings starting with the lowest setting and gradually increasing to a heater setting just high enough to effect dryness without scorching the meat sample. The timer was set at the point where the drying curve reached its highest plateau. Drying curves are illustrated in Plate III.

#### Fat Content Determinations

The first method involved extraction of dried samples in paper thimbles with petroleum ether (special low boiling point for fat determinations) following the procedure described by Official Analytical Chemists, 10th edition (1965) and designated hereafter as the A.O.A.C. method. Samples dried in crucibles to determine moisture percentage were not subjected to ether extraction.



A second procedure involved use of the Steinlite Electronic Fat Tester. The procedure was similar to that described by Furgal (1954) and Everson et al. (1955). A slight modification involved blending for twelve minutes, two minutes at low speed and ten minutes at full speed, in a commercial Waring Blendor, and a simple gravity filtration using a conical funnel with a folded filter paper (Munktell's No. 5). The suction pump, buchner funnel, buchner flask, and Celite filter aid were not used. Sometimes it was necessary to filter twice to obtain a clear filtrate. The equipment used for this method is shown in figure 1.

The Modified Babcock procedure was similar to that described previously by Kelley et al. (1954) using sulfuric acid with centrifuging. A slight modification involved weighing the meat samples into 100 ml. beakers, digesting the material in the beaker, and quantitatively transferring the digested material into Babcock cream bottles. To aid in reading of the upper meniscus, two drops of glymol were added in place of sudan III.

#### Modified Babcock Method (Whalen Modification)

The procedure used was described previously by Whalen (1966). It involves use of hot hydrochloric acid to digest the sample and of dimethyl sulfoxide as a solvent to aid in separation of the fat. Glymol indicator was used to aid in reading of the upper meniscus.

#### Statistical Analysis

Data were analyzed by Analysis of Variance as outlined

by Snedecor (1956). If a significant variance ratio was found, Duncans Multiple Range test was used to determine where significant differences were located.

## RESULTS AND DISCUSSION

Table 1 summarises moisture percentage of three different ground beef samples as affected by method of preparation and method of determination.

Each method detected a significant difference between samples. In general, higher moisture values were obtained by the A.O.A.C. (1) and Moisture Determination Balance methods. This may indicate, as suggested by Wistreich et al. (1960), that there is probably case hardening in this kind of oven drying employing crucibles (A.O.A.C. 2) even though oven temperatures are the same.

The highest moisture values were obtained by the A.O.A.C. (1) method, an oven drying method employing paper thimbles. Greasy spots were observed on some paper thimbles after oven drying but would disappear when ether extracted and dried. Evidently, fat was partially melted, so care must be taken not to spill or lose any fat. Subsequent fat analysis was not performed on crucible dried samples so it is not known if ether extract results were affected.

Analysis of Variance (Table 1a) indicated highly significant F Values (variance ratios) for method of determination and level of moisture in the sample. The method of sample preparation did not cause a significant change although a significant

interaction was noted between moisture level and method of determination.

Duncan's Multiple Range Test (Table 1b) indicated that all means for moisture level were significantly different from each other ( $P < 5\%$ ).

The A.O.A.C. (2) and moisture determination balance agreed closely at low and medium levels; but at high level, the A.O.A.C. (2) was significantly lower than the other two methods.

The A.O.A.C. (1) method recorded significantly higher results than both other methods at the medium level of moisture, significantly higher values than the moisture balance method at the low level of moisture and significantly higher results than the A.O.A.C. (2) method, using crucibles, at the high moisture level. It would appear that moisture is more effectively removed from the sample when paper thimbles were used.

Table 2 presents a record of the moisture percentage for pork sausage samples determined by three different methods. A larger standard deviation seems to be associated with the A.O.A.C. (1) method. This may indicate a difficulty in weighing at a constant dryness, due to the affinity of dry sample and thimble for moisture from the air. The smaller standard deviation of the results with the moisture determination balance may be due to a lack of precision in reading.

Care must be taken in establishing wattage - time conditions as with over-heating, "fat splattering" to the

outside of the weighing pan may result; thereby causing abnormal weight loss.

To effect complete uniform drying of the meat sample, it must be spread thinly and evenly on the aluminum foil pan rapidly. The procedure was easier with pork sausage but ground beef was relatively more sticky.

Analysis of variance (Table 2a) indicated highly significant differences between methods, between moisture levels, but with no significant interaction between method and moisture level.

As shown in Table 2, the lowest moisture values were obtained by the A.O.A.C. (2) method using crucibles and the highest values were obtained by the A.O.A.C. (1) method using thimbles. A significant difference between the two lots of pork sausage was also noted.

Wistreich (1960) felt that the method employing drying in crucibles resulted in case hardening of samples, therefore, sealing in some moisture.

The importance of technique should be emphasized, and methods of drying, cooling and quick weighing should be carefully duplicated from determination to determination. Excessive moisture pick-up by thimbles during a weighing could also result in an apparent higher moisture percentage.

The A.O.A.C. methods take too long to be effective in an active quality control program. Even the forty minutes required for a moisture determination with the moisture determination balance may be too long to alter composition of a

product in process. With this balance, use of more wattage and a shorter time was found to result in an unclear endpoint because of possible overlap of moisture loss and further decompositions.

Another problem results from the fact that only one sample can be subjected to moisture determination at a time. Then too, the balance needs approximately thirty minutes to cool between determinations, since an accurate starting weight cannot be established if the balance is hot. As thermal dehydration on the moisture determination balance is carried out in an open container, the relative humidity in the room and air currents in the room could have some influence on the results.

The higher values obtained by use of paper thimbles could be due to:

- (i) porosity and increased surface area serving to overcome the physical nature of meat such as case-hardening
- (ii) loss of non-water components (volatile and non-volatile)
- (iii) errors in weighing caused by either buoyancy or atmospheric water vapor.

EXPLANATION OF  
PLATE I

Figure 1. Apparatus for Steinlite Electronic Fat Tester Method.

From left to right: Steinlite Electronic Tester. Model LOS Fat and Oil Tester. 250 ml beaker (under Steinlite Test Cell). Support with filter funnel held by clamp. Receiving Flask. Filter paper (Munktell's No. 5) in box. Rheostat (variable speed). Timer. Cylinder (1 ml graduations) 100 ml. Waring Blendor (with blendor jar mounted).

(Analytical balance, spatula - not shown.)

Figure 2. Top panel of Steinlite Electronic Fat Tester.

PLATE I.



Fig. 1



Fig. 2.

EXPLANATION OF  
PLATE II

Modified Babcock Fat Columns

#1 and 2. Modified Babcock (Whalen Modification)  
glymol indicator (red meniscus reader) was  
added in both columns.

#3 and 4. Modified Babcock (using acetic and  
sulfuric acids). Glymol indicator was  
added to #3. No glymol in #4.



## PLATE II.

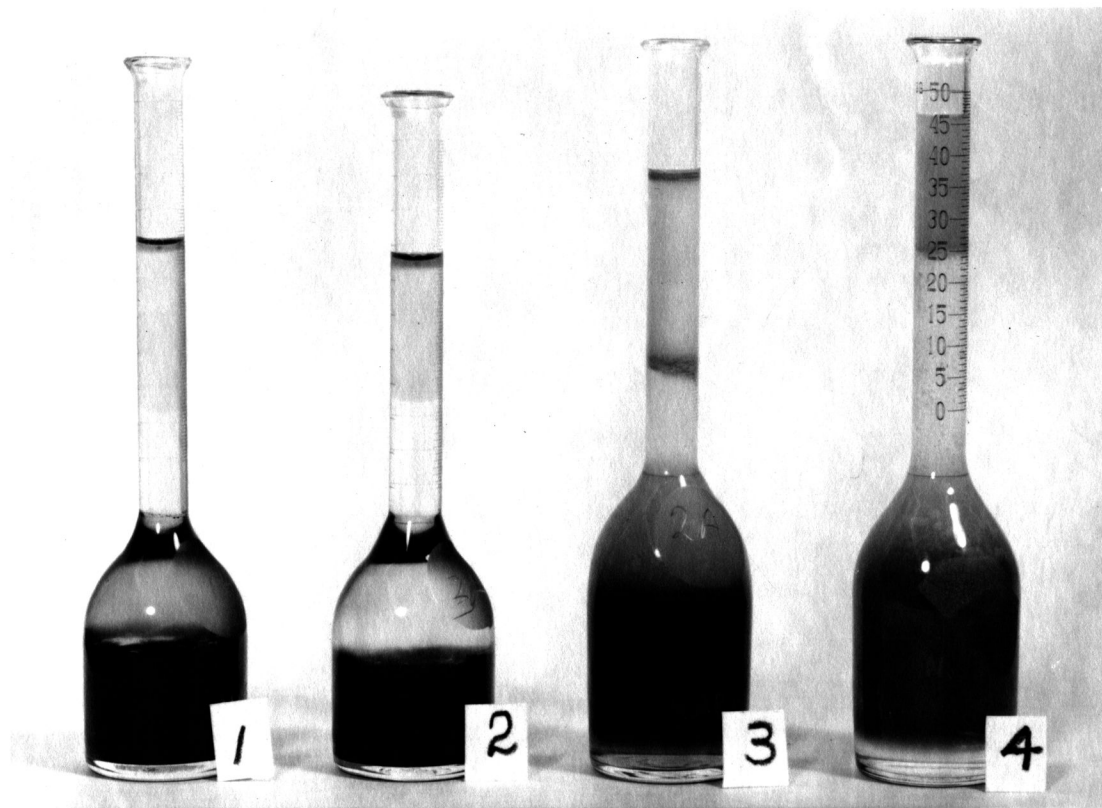


Table 1

A Comparison of Moisture Content  
(Percentage) of Ground Beef as Determined  
by Three Methods\*

| Method  | : Low Moisture<br>: Level    | : Medium<br>: Level          | : High<br>: Level            | : Average for<br>: Method <sup>b</sup> |
|---|------------------------------|------------------------------|------------------------------|--|
| A.O.A.C. (1) - A <sup>#</sup><br>(Paper Thimble) - B <sup>+</sup> | : 57.94± .49<br>: 57.75± .66 | : 60.30±1.68<br>: 60.22± .42 | : 63.13± .48<br>: 63.03± .78 | : 60.39                                |
| A.O.A.C. (2) - A <sup>#</sup><br>(Crucible) - B <sup>+</sup>      | : 56.67±1.96<br>: 57.97±1.01 | : 58.56± .55<br>: 58.74± .61 | : 61.50± .55<br>: 61.62±1.11 | : 59.18                                |
| Moisture Balance- A <sup>#</sup><br>- B <sup>+</sup>              | : 56.73± .01<br>: 57.03± .05 | : 58.70± .64<br>: 59.53± .52 | : 62.55± .01<br>: 63.43± .33 | : 59.66                                |
| Average for<br>Sample <sup>a</sup>                                | : 57.35± .70                 | : 59.34± .74                 | : 62.60± .54                 | :                                      |

\*for full data see Table 1 (c)

#A = blended sample

+B = ground

<sup>b</sup>all means for method significantly different (Prob. < 5%)

<sup>a</sup>all means for moisture level significantly different (Prob. < 5%) from each other

Table 1 (a) Moisture Content of Ground Beef  
Samples by Three Determination Methods

Analysis of Variance

| Source of Variation   | : Degrees<br>: of<br>: Freedom | : Sum<br>: of<br>: Squares | : Mean<br>: Squares | :<br>:<br>: F |
|---|--------------------------------|----------------------------|---------------------|---------------|
| Total   | 117                            | 682.2154                   |                     |               |
| Determination Method  | 2                              | 30.7890                    | 15.3945             | 20.27**       |
| Moisture Level  | 2                              | 555.3882                   | 277.6941            | 365.68**      |
| Method of Preparation   | 1                              | 1.4856                     | 1.4856              | 1.96          |
| Determination Method<br>X Moisture Level                            | 4                              | 11.5028                    | 2.8757              | 3.78*         |
| Determination Method<br>X Method of Preparation                     | 2                              | 4.1712                     | 2.0856              | 2.75          |
| Moisture Level<br>X Method of Preparation                           | 2                              | 0.1686                     | 0.0843              | 0.01          |
| Determination Method<br>X Moisture Level<br>X Method of Preparation | 4                              | 2.7743                     | 0.6936              | 0.91          |
| Error   | 100                            | 75.9357                    | 0.7594              |               |

\*Probability < 5%  
\*\*Probability < 1%

Table 1 (b) Moisture Content (Mean Percentage)  
of Ground Beef Samples  
by Three Determination Methods<sup>†</sup>

Moisture Level X Determination Method Interaction

| Method                     | :Low Moisture:<br>: Level : | Medium<br>: Level : | High<br>: Level :  | Method<br>: Average <sup>#</sup> |
|----------------------------|-----------------------------|---------------------|--------------------|----------------------------------|
| A.O.A.C. (1)               | 57.84 <sup>b</sup>          | 60.26 <sup>d</sup>  | 63.08 <sup>f</sup> | 60.39                            |
| A.O.A.C. (2)               | 57.32 <sup>ab</sup>         | 58.65 <sup>c</sup>  | 61.56 <sup>e</sup> | 59.18                            |
| Moisture Balance           | 56.88 <sup>a</sup>          | 59.12 <sup>c</sup>  | 62.99 <sup>f</sup> | 59.66                            |
| Batch Average <sup>*</sup> | 57.35                       | 59.34               | 62.54              |                                  |

<sup>†</sup>All means with the same superscript are not significantly different at 5% level of probability as tested by Duncan's Multiple Range Test.

<sup>#</sup>All method averages significantly different ( $P < 5\%$ ) from each other.

<sup>\*</sup>All fat level (batch means) averages significantly different ( $P < 5\%$ ) from each other.

Table 2

A Comparison of Moisture Content (Percentage)  
of Fresh Pork Sausage Determined by Three Methods

|                                      | LOT 1                    |                         |                         | LOT 2                    |                         |                         |
|--------------------------------------|--------------------------|-------------------------|-------------------------|--------------------------|-------------------------|-------------------------|
|                                      | A.O.A.C.(1)              | A.O.A.C.(2)             | Moisture Balance        | A.O.A.C.(1)              | A.O.A.C.(2)             | Moisture Balance        |
|                                      | 51.46                    | 46.32                   | 48.60                   | 56.19                    | 52.50                   | 55.00                   |
|                                      | 48.97                    | 45.75                   | 48.80                   | 54.97                    | 52.75                   | 54.20                   |
|                                      | 50.10                    | 45.80                   | 48.70                   | 54.45                    | 51.40                   | 54.50                   |
|                                      | 49.68                    | 46.40                   | 48.60                   | 57.62                    | 50.27                   | 54.70                   |
|                                      |                          |                         |                         | 54.06                    | 52.25                   | 54.50                   |
|                                      |                          |                         |                         | 54.85                    | 50.99                   | 54.80                   |
|                                      |                          |                         |                         | 54.85                    | 52.60                   | 54.60                   |
|                                      |                          |                         |                         | 54.22                    | 51.80                   | 55.60                   |
| Average                              | 50.05 <sup>*</sup> ±1.04 | 46.07 <sup>*</sup> ±.34 | 48.68 <sup>*</sup> ±.01 | 55.15 <sup>*</sup> ±1.19 | 51.83 <sup>*</sup> ±.87 | 54.66 <sup>*</sup> ±.27 |
| Method Mean<br>(both lots)           | 53.45 <sup>c</sup>       | 49.90 <sup>a</sup>      | 52.72 <sup>b</sup>      |                          |                         |                         |
| Lot Mean <sup>†</sup><br>(3 methods) |                          | 48.27                   |                         |                          | 53.90                   |                         |

†Lot 1 mean significantly lower than Lot 2 (P < 1%).

<sup>a</sup>For method average, all method means with same superscript are not significantly different at 5% level of probability using Duncan's Multiple Range Test.

\*All means significantly different from each other.

Table 2 (a)      Moisture Content (Percentage)  
 Determination in Pork Sausage  
 by Three Methods

Analysis of Variance

| Source of Variation                      | : Degrees<br>: of<br>: Freedom | : Sum<br>: of<br>: Squares | : Mean<br>: Squares | :<br>:<br>: F |
|--|--------------------------------|----------------------------|---------------------|---------------|
| Total Determinations                     | 35                             | 356.0970                   |                     |               |
| Determination Method                     | 2                              | 83.4137                    | 41.7068             | 64.14**       |
| Moisture Level                           | 1                              | 252.0387                   | 252.0387            | 387.51**      |
| Determination Method<br>X Moisture Level | 2                              | 1.1310                     | 0.5655              | 0.87          |
| Error                                    | 30                             | 19.5136                    | 1.6504              |               |

\*\*Probability < 1%

Results of fat analysis of three different ground beef samples prepared in two ways and analyzed by four different methods are presented in Table 3. Complete data is shown in Table 3d in the appendix.

Analysis of Variance of fat values obtained by all four methods for ground beef (Table 3a) indicated that major sources of variation were due to fat level in sample and determination method ( $P < 1\%$ ). The method of sample preparation did not have a significant effect upon results. There was, however, a highly significant interaction between fat level and determination method and between method of sample preparation and determination method. The fat level and method of sample preparation interaction was significant at  $P < 5\%$ .

As shown in Tables 3 and 3a, in general, the lowest fat values were obtained by the A.O.A.C. method at all levels of fat, while the percentage values obtained by the Steinlite Fat Tester were generally the highest. The low fat values by the A.O.A.C. method may be due to inherent errors in this crude fat determination as suggested by Wiley (1907) and Bixby *et al.* (1954).

Duncan's Multiple Range Test (Table 3b) indicated that at the low fat level, the weighted fat at mean values obtained by the Steinlite Electronic Fat Tester and Modified Babcock (Whalen modification) were not significantly different ( $P < 5\%$ ) from each other but were significantly higher than the official method (A.O.A.C.) and the modified Babcock method. The A.O.A.C.

Table 3 A Comparison of Fat Content (Percentage)  
of Ground Beef Determined by Four Methods  
and Prepared in Two Ways

| DETERMINATION AND<br>PREPARATION METHOD† |    | : Low Fat<br>: Level | : Medium Fat:<br>: Level | : High Fat<br>: Level |
|--|----|----------------------|--------------------------|-----------------------|
| A.O.A.C.                                 | -A | 16.26± .44           | 21.10± .94               | 24.08± .55            |
|  | B  | 16.61± .75           | 20.74± .74               | 24.42± .50            |
| Average (A and B)                        |    | <u>16.44± .51</u>    | <u>20.92± .84</u>        | <u>24.25± .53</u>     |
| Steinlite                                | -A | 17.30± .48           | 22.60± .48               | 26.71±1.37            |
|  | B  | 18.44± .38           | 21.97± .64               | 26.34± .73            |
| Average (A and B)                        |    | <u>17.91± .43</u>    | <u>22.29± .56</u>        | <u>26.53±1.05</u>     |
| Modified Babcock                         | -A | 16.93± .32           | 20.76± .84               | 26.43±1.18            |
|  | B  | 17.03± .65           | 20.46± .73               | 26.07±1.03            |
| Average (A and B)                        |    | <u>16.98± .49</u>    | <u>20.61± .79</u>        | <u>26.25±1.11</u>     |
| Modified Babcock (Whalen)-A              |    | 17.55± .54           | 21.10± .52               | 25.02± .96            |
|  | B  | 17.43±1.48           | 21.13± .87               | 25.00± .36            |
| Average (A and B)                        |    | <u>17.49±1.01</u>    | <u>21.12± .70</u>        | <u>25.01± .66</u>     |

†Preparation Method - A is blended in Waring Blendor; B is ground and mixed 3 times.



Table 3 (a)      Fat Content Determinations  
                    on Ground Beef  
                    by Four Methods

Analysis of Variance

| Source of Variation                                       | : Degrees<br>: of<br>: Freedom | : Sum<br>: of<br>: Squares | : Mean<br>: Squares | :<br>:<br>: F |
|---|--------------------------------|----------------------------|---------------------|---------------|
| Total Determinations                                      | 191                            | 2,075.9966                 |                     |               |
| Fat Level   | 2                              | 1,894.8339                 | 947.4169            | 2,169.99**    |
| Method of Sample<br>Preparation                           | 1                              | .0022                      | .0022               | 0.01          |
| Determination Method                                      | 3                              | 29.7888                    | 9.9296              | 22.74**       |
| Fat Level X Method of<br>Sample Preparation               | 2                              | 3.7449                     | 1.8724              | 4.29*         |
| Fat Level X Determina-<br>tion Method                     | 6                              | 62.0420                    | 10.3403             | 23.68**       |
| Method of Sample<br>Preparation<br>X Determination Method | 3                              | 9.6187                     | 3.2062              | 7.34**        |
| Error   | 174                            | 75.9662                    | 0.4366              |               |

\*Probability < 5%  
\*\*Probability < 1%

Table 3 (b) Fat Content Determinations on  
Ground Beef by Four Methods

Fat Level X Determination Method Interaction  
(Weighted Mean Values)<sup>†</sup>

|                                       | :<br>: A.O.A.C.    | :<br>: Steinlite   | : Modified:<br>: Babcock | : Babcock<br>: (Whalen) |
|---------------------------------------|--------------------|--------------------|--------------------------|-------------------------|
| Low Fat Level                         | 16.44 <sup>a</sup> | 17.91 <sup>c</sup> | 16.98 <sup>b</sup>       | 17.49 <sup>c</sup>      |
| Medium Fat Level                      | 20.92 <sup>d</sup> | 22.28 <sup>e</sup> | 20.61 <sup>d</sup>       | 21.12 <sup>d</sup>      |
| High Fat Level                        | 24.25 <sup>f</sup> | 26.52 <sup>h</sup> | 26.25 <sup>h</sup>       | 25.01 <sup>g</sup>      |
| Determination Method<br>Weighted Mean | 20.54*             | 22.24*             | 21.28                    | 21.20                   |

<sup>†</sup>All values with the same superscript are not significantly different at 5% level of probability, by Duncan's Multiple Range Test.

\*Differs from other means for determination method (P < 5%).

method results were significantly lower than all other methods.

At the medium fat level, the percent values obtained by the official method and both modified Babcock methods were not significantly different ( $P < 5\%$ ), but the Steinlite values were significantly higher than the other three methods.

At the high level of fat, values obtained by the Steinlite Fat Tester and Modified Babcock were not significantly different from each other but were significantly higher than the other two. The lowest value was found by the A.O.A.C. method, and the highest value by the Steinlite Fat Tester.

For the high fat level sample, the standard deviation tended to be higher in the Steinlite and Modified Babcock results (Table 3). At the low fat level, the Modified Babcock (Whalen) method had the largest standard deviation. Perhaps it is dangerous to compare standard deviations when they could not be subjected to statistical analysis, and when a small number of determinations were utilized. However, they might give a comparative idea of variation encountered in using a method.

It can also be noted that at the low and medium levels of fat, the A.O.A.C. method and Modified Babcock method were closely related and had lower fat values than the other two methods.

Addition of three per cent sodium chloride had a highly significant depressing effect on the results obtained by the Steinlite Electronic Fat Tester as shown in Table 4 and by analysis of variance in Table 4a. When 3% sodium chloride

Table 4      Effect of 3% Added Salt on Steinlite  
 Electronic Fat Tester Results for  
 Fat Content (Percentage) on  
 Ground Beef Samples - Medium Level of Fat

| No Salt in Sample       |                         | : | 3% Salt Added                |                         |
|-------------------------|-------------------------|---|------------------------------|-------------------------|
| <u>A</u> <sup>*</sup>   | <u>B</u> <sup>*</sup>   | : | <u>A</u> <sup>*</sup>        | <u>B</u> <sup>*</sup>   |
| 22.96                   | 21.85                   | : | 20.17                        | 20.72                   |
| 22.71                   | 21.03                   | : | 20.20                        | 21.04                   |
| 22.18                   | 22.17                   | : | 20.83                        | 20.59                   |
| 22.25                   | 21.57                   | : | 20.94                        | 21.05                   |
| 23.00                   | 22.25                   | : |                              |                         |
| 22.44                   | 21.30                   | : |                              |                         |
| 23.52                   | 23.24                   | : |                              |                         |
| 22.15                   | 22.16                   | : |                              |                         |
| 22.18                   | 22.17                   | : |                              |                         |
| <b>Mean*</b>            | 22.60 <sup>c</sup> ±.48 | : | 20.53 <sup>a</sup> ±.41      | 20.85 <sup>a</sup> ±.23 |
| No Salt Samples = 22.28 |                         | : | Salt Added Samples = 20.69** |                         |

\*A - blended in Waring Blendor; B - ground and mixed three times

\*All means with same superscript are not significantly different at 5% level of probability by Duncan's Multiple Range Test.

\*\*Mean for samples with 3% salt added, was significantly lower than mean for samples with no salt added.

Table 4 (a) Effect of 3% Added Salt on Fat  
 Determinations of Ground Beef  
 by the Steinlite Method  
 (Medium Fat Level Only)

Analysis of Variance

| Source of Variation                   | : Degrees<br>: of<br>: Freedom | : Sum<br>: of<br>: Squares | : Mean<br>: Squares | :<br>:<br>: F |
|---------------------------------------|--------------------------------|----------------------------|---------------------|---------------|
| Total Determinations                  | 25                             | 21.8407                    |                     |               |
| Method of Preparation                 | 1                              | 0.7412                     | 0.7412              | 2.80          |
| Salt Level                            | 1                              | 14.0460                    | 14.0460             | 53.06**       |
| Method of Preparation<br>X Salt Level | 1                              | 1.2306                     | 1.2306              | 4.65*         |
| Error                                 | 22                             | 5.8229                     | 0.2647              |               |

\*Probability < 5%

\*\*Probability < 1%

(common salt) was added, the results of fat analysis obtained were 1.59% lower as compared to the non-salt sample. The fat content of the salt-added samples was not determined by any of the other methods to explain the low values obtained. This result differs from those of Furgal (1954) who found no difference in Steinlite results attributable to addition of 3% salt to the solvent. He used samples with a higher fat level and the salt was added to both pure solvent and solvent containing fats which may have affected the depressing action of sodium chloride on final results. The fat mean value of salt-added samples (A) prepared by homogenizing in a Waring Blendor and (B) prepared by grinding and mixing was not significantly different. However, a significant variance ratio was calculated for the interaction between method of preparation and salt level ( $P < 5\%$ ).

A comparison of fat content percentages determined by four methods on fresh pork sausage is shown in Table 5. The lowest mean fat value was obtained by the A.O.A.C. method and the highest mean fat value was obtained by the Modified Babcock (Whalen) method. The results obtained by the Steinlite Electronic Fat Tester were closest to the A.O.A.C. results, followed by the usual Modified Babcock method. The fat percentage of  $32.03 \pm 1.02$  obtained by the A.O.A.C. and the fat percentage of  $33.25 \pm .23$  by the Steinlite would compare favorably with the previous findings of Furgal (1954) who reported that the Steinlite method had less variation than the A.O.A.C. ( $P < 5\%$ ).

Analysis of variance showed that the fat values obtained by each method were significantly different from each other ( $P < 5\%$ ) and that the method of determination was a highly significant source of variation. (Table 5a)

It was, however, evident that all the four methods distinguished between the three levels of fat in ground beef samples.

The average time in minutes taken to complete fat content determinations exclusive of sample preparation and assembly of apparatus was as follows:

|                                     |                 |
|-------------------------------------|-----------------|
| Steinlite method                    | 19 to 28        |
| Modified Babcock Method             | 17 to 25        |
| Modified Babcock (Whalen) Method    | 11 to 15        |
| A.O.A.C. Method (Soxhlet Extractor) | 50 - 52 (hours) |

Method of sample preparation had no significant effect on the results obtained by any of the four methods although interactions with method of determination and fat level had been found to be significant.

Hagan et al. (1967) extracted lipids from raw beef lean by using various solvent systems, three drying procedures and two sample preparation methods. Their study indicated that sample preparation had no significant effect on the results of samples which contained higher proportions of extractable lipid. When the results from different drying methods and method solvent-system combinations were compared, no significant differences in results were found, regardless of cut, between methods of sample preparation.

Table 5                    A Comparison of Fat Content  
(Percentage) Determined by Four Methods  
                                 on Fresh Pork Sausage

|                       | :<br>:<br>: A.O.A.C. | :<br>:<br>: Steinlite | :<br>:<br>: Modified<br>: Babcock | :<br>:<br>: Modified<br>: Babcock<br>: (Whalen) |
|-----------------------|----------------------|-----------------------|-----------------------------------|---|
|                       | 33.07                | 33.51                 | 35.00                             | 35.00   |
|                       | 31.00                | 32.98                 | 34.30                             | 35.50   |
|                       | 31.34                | 33.17                 | 33.80                             | 35.80   |
|                       | 32.74                | 33.36                 | 34.20                             | 35.40   |
| Mean*                 | 32.03 <sup>a</sup>   | 33.25 <sup>b</sup>    | 34.32 <sup>c</sup>                | 35.42 <sup>d</sup>                              |
| Standard<br>Deviation | ±1.02                | ±.23                  | ±.50                              | ±.33  |

\*All means with same superscript are not significantly different.  
(P < 5%).

Table 5 (a)                Fat Level in Pork Sausage  
                                 by Four Methods of Determination

Analysis of Variance

| Source of Variations  | : Degrees<br>: of<br>: Freedom | : Sum<br>: of<br>: Squares | : Mean<br>: Squares | :<br>:<br>: F |
|-----------------------|--------------------------------|----------------------------|---------------------|---------------|
| Total                 | 15                             | 29.6103                    |                     |               |
| Determination Methods | 3                              | 25.2539                    | 8.4180              | 23.19**       |
| Error                 | 12                             | 4.3564                     | .3630               |               |

\*\*Probability < 1%



Individual variations in fat values between single determinations for each method were encountered. These variations could have been caused by variation in the chemical composition of the samples; errors due to sampling, weighing of sample, incorrect measurements of reagents, erroneous recording of results and errors due to inadequate experience of the operator.

Comparing the results obtained by the three rapid methods with the A.O.A.C. method, indicated that the difference in fat values increased with increase in fat level. At the low fat level, the difference between the lowest and highest mean fat value was within 1.5%, at medium fat level within 1.7% and at high fat level within 2.3% when all four methods were compared.

#### Critique of Fat Analysis Methods

The A.O.A.C. method for fat takes too long to be useful for active quality control. The low fat values consistently obtained still cause concern. Volatile components may be responsible or ether insoluble components which are not determined or both these factors could jointly account for the lower fat values obtained. Bixby et al. (1954) have suggested that the fat in the center of the sample may not be accessible to dry ether.

The small sample of four to six grams used for the A.O.A.C. method increased difficulty of getting a representative sample, but on the other hand, results in less product being used in the analysis.

The Steinlite Electronic Fat Tester method is a rapid analytical method and the instrument is rugged enough for non-professional handling. The unpleasant odor of the solvent with possible harmful effects of the orthodichlorobenzene solvent makes it less useful for in-plant operation. The harmful effects could be minimized by using a hood and careful handling, but the odor effects would appear difficult to eliminate. Furthermore, the instrument has to be standardized carefully each time, and the balance knob is in the wrong place making it too easy to reach and move accidentally (Fig. 2).

Since 50 to 100 grams of meat sample are employed for each determination, it might be easier to take representative samples.

A sample with high fat content seemed to be easier to prepare for testing with the Steinlite, in that filtration was faster, and results were obtained in twenty to thirty minutes. On the other hand, a sample of less than 18% fat content had to be larger, took longer to extract and filtration was not as easy. Preliminary experiments revealed flocculation or precipitation within the filtrate requiring further filtration of four or five times more. The filtrate so obtained had to be warmed up in a water bath to the desired temperature range of 75°F to 95°F. The effect of salt on samples with low fat content included precipitation of the filtrate in the test cell, causing an erratic drift in the meter and making it difficult at times to obtain a reading.

As for the Modified Babcock method using acetic and sulfuric acid, meat samples with high content of connective tissue could be difficult to digest even with heating. Treating the sample with glacial acetic acid is a predigestion and is supposed to keep the sample in contact with sulfuric acid. Preliminary experiments showed that samples with high connective tissue content separated out on addition of concentrated sulfuric acid such that the connective tissue floated in the beaker and was protected by the separated fat from the action of the acid. It took about ten minutes longer to digest some of this connective tissue without charring the sample. Adding more acid seemed to result in more discoloration. Undigested buoyant material tended to hinder separation of fat in the cream bottle especially, if the volume of material in the cream bottles filled the lower part of the bottle to the base of the stem. Prolonged centrifugation in such a case would sometimes cause a solid undesirable layer of material, making it difficult for fat to separate out into the column when water was added. The method as described by Kelley (1954) calls for centrifuging two times. The first centrifugation immediately after digestion, where the volume is kept to a minimum, helps to sediment undigested matter and could not be sacrificed for time saving without loss of accuracy. The success of the final centrifugation would depend in part on the first centrifugation. The problem of charring would be important where the meat sample is difficult to digest.

The uneven meniscus, especially on lower end of column, was a problem in prepared meats and where excessive reagents were used so that less water could be added. Use of a red glymol indicator improved the upper meniscus and is used by the dairy industry for Babcock determination to make the meniscus more clearly visible.

It would be logical to suppose that weighing sample into the bottle so as to carry on all digestion into the bottle would minimize errors caused by transferring digested material into the cream bottle.

Modified Babcock (Whalen) was found to be a shorter procedure than the usual Modified Babcock by five to seven minutes. The procedure has less digestion problems but use of hot concentrated Hydrochloric Acid necessitates the use of a hood. The other reagent, dimethyl sulfoxide can be dangerous if inhaled or if it comes into contact with skin.

Variations were noticed in temperatures of the treated samples. The lack of uniformity in temperature control would cause some samples to solidify during centrifugation resulting in distorted menisci. Incorporating use of a water bath into the procedure could be advantageous, if the co-efficient of expansion of fat is considered significant, as it would serve to standardize temperature. It might also be beneficial due to the ease of reading a liquid meniscus. However, the lower meniscus is much more clear in this procedure with ground beef samples. For pork sausage, it was as difficult to estimate the lower meniscus due to a "sticky, dirty" mass at the interface of separated fat which may have been caused by the spices.

### SUMMARY AND CONCLUSIONS

Rapid methods for the determination of fat and moisture content of ground beef and pork sausage samples have been compared with the official methods of analysis of the Association of Official Analytical Chemists. Ground beef samples were prepared in two ways (ground and mixed three times or blended in a Waring Blendor) and consisted of three levels of fat and moisture content. Fat levels were approximately 17%, 21% and 25% for low, medium and high, respectively.

The moisture determination balance (OHAUS) method was compared with the A.O.A.C. method employing paper thimbles and the A.O.A.C. method involving use of crucibles. Results were obtained in forty minutes by using the moisture determination balance method as against a minimum of 16 hours required with the air oven method.

The lowest moisture values were obtained by the A.O.A.C. (crucible) method, while the highest moisture values were obtained by the A.O.A.C. (paper thimble) method on ground beef and pork sausage samples, for all levels of moisture content. The results obtained with the rapid moisture balance, more closely approached the results of the official method using paper thimbles than those where crucibles were employed.

Three rapid methods for the determination of fat content in ground beef and pork sausage samples, were compared with the A.O.A.C. method of dry ether extraction. The three methods were: Steinlite Electronic Fat Tester, regular Modified Babcock (using

Acetic acid and Sulfuric acid) and Modified Babcock by Whalen (using Hydrochloric acid and Dimethylsulfoxide).

The effect of 3% added salt (sodium chloride) on the Steinlite Electronic Fat Tester results was determined using ground beef samples of medium fat level.

It was possible to complete fat content determinations by the three rapid methods within thirty minutes as compared to over fifty hours required for the complete A.O.A.C. procedure for fat employing Soxhlet extractors.

All the methods employed for the determination of fat and moisture content in all samples tested, differentiated between the levels of fat and moisture consistently. In most cases, the results of each method were significantly different from each other.

With only one exception, the lowest mean ground beef fat content, was obtained by A.O.A.C. method for all levels of fat. The highest mean fat values, were obtained by the Steinlite Electronic Fat Tester method, for all levels of fat. At low and medium levels of fat, the Modified Babcock method (using Acetic acid and Sulfuric acid) yielded results which compared more closely with the A.O.A.C. method than either the Steinlite or Modified Babcock by Whalen (using Hydrochloric acid and Dimethyl sulfoxide).

The major source of variation in all four methods of fat determination was found to be the level of fat in the sample.

Another significant source of variation was the method of determination. Method of sample preparation did not contribute appreciable variation.

Addition of 3% sodium chloride (common salt) to ground beef samples of medium fat level with mean fat percentage of 22.28%, significantly depressed the results obtained by the Steinlite method by a mean fat value of 1.59%.

The results obtained by the Steinlite method for fat content in pork sausage were more close to the A.O.A.C. method than the Babcock methods.

From the findings of this study, it could be concluded that the rapid fat determination methods studied could be used with advantage in active product quality control to give results comparable to the A.O.A.C. method within thirty minutes.

The choice of method would be considered against the estimated level of fat in the sample to be tested, but the added substances could be an important consideration where salt and the Steinlite are involved.

It was apparent that for ground beef samples of low and medium fat levels, the modified Babcock (using acetic and sulfuric acids) method gave results identical to the A.O.A.C. method of dry ether extraction. For the high fat level, the modified Babcock method by Whalen could be considered more reliable.

If all the four methods studied were considered for fat content determinations in ground beef (15 to 25% fat) and pork sausage samples, the modified Babcock (using acetic and

sulfuric acids) would be the overall rapid method of choice. Other advantages could be readily available inexpensive apparatus, simple procedure, use of common industrial reagents and adaptability to in-plant operation.

The study showed the importance of standardization of materials and procedures in methods of chemical analysis on ground meat samples.



## APPENDIX

Table 1 (c) Moisture Content Determinations on Ground Beef  
Percent Values on "as received" Basis

| Moisture<br>Level | METHODS        |       |                |       |                    |       |
|-------------------|----------------|-------|----------------|-------|--------------------|-------|
|                   | : A.O.A.C. (1) |       | : A.O.A.C. (2) |       | : Moisture Balance |       |
|                   | : A            | B     | : A            | B     | : A                | B     |
|                   | 58.41          | 57.85 | : 52.86        | 57.99 | : 56.70            | 57.00 |
|                   | 58.82          | 56.87 | : 56.41        | 56.05 | : 56.80            | 57.00 |
|                   | 57.06          | 56.91 | : 57.83        | 58.23 | : 56.60            | 57.10 |
|                   | 58.06          | 57.65 | : 57.20        | 59.07 | : 56.80            | 57.00 |
|                   | 57.95          | 57.83 | : 58.23        | 58.27 | :                  |       |
| Low               | 57.85          | 59.24 | : 57.47        | 58.21 | :                  |       |
|                   | 58.08          | 57.08 | :              |       | :                  |       |
|                   | 57.24          | 57.74 | :              |       | :                  |       |
|                   | 57.69          | 57.79 | :              |       | :                  |       |
|                   | 58.17          | 58.19 | :              |       | :                  |       |
|                   | 58.05          | 58.00 | :              |       | :                  |       |
| Mean              | : 57.94        | 57.74 | : 56.67        | 57.97 | : 56.73            | 57.03 |
| S.D.              | : ±.94         | ±.66  | : ±1.96        | ±1.01 | : ±.01             | ±.00  |

NOTE: A = Sample prepared by grinding, mixing 3 times and blended in Waring Blendor.

B = Sample prepared by grinding and mixing 3 times.

S.D. = Standard deviation.

## APPENDIX

Table 1 (c) Continued.

| Moisture<br>Level | METHODS        |       |                |       |                   |       |
|-------------------|----------------|-------|----------------|-------|-------------------|-------|
|                   | : A.O.A.C. (1) |       | : A.O.A.C. (2) |       | :Moisture Balance |       |
|                   | : A            | B     | : A            | B     | : A               | B     |
|                   | 59.41          | 59.91 | : 58.03        | 58.28 | : 58.20           | 60.00 |
|                   | 59.76          | 59.87 | : 59.06        | 59.40 | : 58.10           | 59.80 |
|                   | 60.06          | 60.28 | : 58.15        | 58.18 | : 59.50           | 59.50 |
|                   | 64.33          | 60.75 | : 59.01        | 59.13 | : 59.00           | 58.80 |
| Medium            | 59.86          | 60.02 | :              |       | :                 |       |
|                   | 61.37          | 60.45 | :              |       | :                 |       |
|                   | 59.83          | 59.94 | :              |       | :                 |       |
|                   | 59.64          | 60.63 | :              |       | :                 |       |
|                   | 58.48          | 59.55 | :              |       | :                 |       |
| Mean              | : 60.30        | 60.22 | : 58.56        | 58.74 | : 58.70           | 59.53 |
| S.D.              | : ±1.68        | ±.42  | : ±.55         | ±.61  | : ±.64            | ±.52  |

## APPENDIX

Table 1 (c) Continued.

| Moisture<br>Level | METHODS        |       |                |       |                   |       |
|-------------------|----------------|-------|----------------|-------|-------------------|-------|
|                   | : A.O.A.C. (1) |       | : A.O.A.C. (2) |       | :Moisture Balance |       |
|                   | : A            | B     | : A            | B     | : A               | B     |
|                   | 62.45          | 63.53 | : 60.80        | 59.98 | : 62.40           | 63.80 |
|                   | 62.78          | 64.10 | : 61.03        | 61.61 | : 62.50           | 63.00 |
|                   | 62.64          | 64.06 | : 61.84        | 62.00 | : 62.50           | 63.50 |
|                   | 62.98          | 63.19 | : 61.35        | 62.06 | : 62.80           | 63.40 |
|                   | 64.19          | 62.99 | : 61.77        | 60.86 | :                 |       |
| High              | 63.07          | 63.09 | : 62.18        | 63.23 | :                 |       |
|                   | 63.67          | 62.40 | :              |       | :                 |       |
|                   | 63.05          | 62.91 | :              |       | :                 |       |
|                   | 63.12          | 62.79 | :              |       | :                 |       |
|                   | 63.39          | 61.28 | :              |       | :                 |       |
|                   | 63.10          | 62.98 | :              |       | :                 |       |
| Mean              | : 63.13        | 63.03 | : 61.50        | 61.62 | : 62.55           | 63.43 |
| S.D.              | : ±.48         | ±.78  | : ±.53         | ±1.11 | : ±.01            | ±.33  |

APPENDIX

Table 3 (a) Fat Content (Percentage) Determinations on Ground Beef

| Level | A.O.A.C. |       | Steinlite |       | Mod. Babcock |       | Mod. Babcock (Whalen) |       |
|-------|----------|-------|-----------|-------|--------------|-------|-----------------------|-------|
|       | A        | B     | A         | B     | A            | B     | A                     | B     |
|       | 15.50    | 16.49 | 16.55     | 18.82 | 17.20        | 17.00 | 17.80                 | 17.20 |
|       | 16.06    | 16.53 | 17.69     | 18.18 | 17.00        | 17.00 | 18.00                 | 17.40 |
|       | 16.13    | 15.63 | 16.71     | 18.78 | 16.80        | 16.60 | 17.20                 | 18.00 |
|       | 17.06    | 16.62 | 17.94     | 18.77 | 16.40        | 17.60 | 16.60                 | 17.00 |
| Low   | 16.32    | 16.59 | 17.65     | 18.75 | 16.70        | 18.00 | 18.00                 | 17.00 |
|       | 16.32    | 16.28 | 17.45     | 18.93 | 17.40        | 17.20 | 17.00                 | 18.00 |
|       | 16.34    | 16.55 | 17.44     | 17.70 | 17.20        | 17.00 | 17.80                 | 17.80 |
|       | 16.77    | 17.60 | 17.60     | 17.61 | 17.00        | 15.80 | 18.00                 | 17.00 |
|       | 16.28    | 15.73 |           |       |              |       |                       |       |
|       | 15.77    | 18.12 |           |       |              |       |                       |       |
| Mean  | 16.26    | 16.61 | 17.38     | 18.44 | 16.93        | 17.03 | 17.55                 | 17.43 |
| S.D.  | ±.44     | ±.75  | ±.48      | ±.38  | ±.32         | ±.65  | ±.54                  | ±.19  |

APPENDIX

Table 3 (e) Continued.

% Fat Values

| Level  | A.O.A.C. |       | : | Steinlite |       | : | Mod. Babcock |       | : | Mod. Babcock (Whalen) |       |
|--------|----------|-------|---|-----------|-------|---|--------------|-------|---|-----------------------|-------|
|        | A        | B     |   | A         | B     |   | A            | B     |   | A                     | B     |
|        | 20.11    | 20.66 | : | 22.96     | 21.85 | : | 21.80        | 21.20 | : | 21.50                 | 21.00 |
|        | 20.96    | 21.66 | : | 22.71     | 21.03 | : | 19.20        | 20.00 | : | 20.70                 | 21.80 |
|        | 22.86    | 20.18 | : | 22.18     | 22.17 | : | 20.50        | 19.20 | : | 21.00                 | 20.40 |
|        | 21.50    | 19.59 | : | 22.25     | 21.57 | : | 21.00        | 20.60 | : | 21.20                 | 20.50 |
| Medium | 20.63    | 20.51 | : | 23.00     | 22.25 | : | 21.20        | 20.60 | : | 21.50                 | 20.50 |
|        | 20.45    | 20.34 | : | 22.44     | 21.30 | : | 21.20        | 20.80 | : | 20.00                 | 23.00 |
|        | 22.30    | 20.62 | : | 23.52     | 23.24 | : | 21.00        | 21.00 | : | 21.00                 | 20.60 |
|        | 20.88    | 21.23 | : | 22.15     | 22.16 | : | 21.30        | 19.50 | : | 21.20                 | 20.70 |
|        | 20.23    | 21.91 | : | 22.18     | 22.17 | : | 19.60        | 21.20 | : | 21.80                 | 21.70 |
| Mean   | 21.10    | 20.74 | : | 22.60     | 21.97 | : | 20.76        | 20.46 | : | 21.10                 | 21.13 |
| S.D.   | ±.94     | ±.74  | : | ±.48      | ±.64  | : | ±.84         | ±.52  | : | ±.52                  | ±.87  |

APPENDIX

Table 3 (a) Continued.

% Fat Values

| Level | A.O.A.C. |       | Steinlite |       | Mod. Babcock |       | Mod. Babcock (Whalen) |       |
|-------|----------|-------|-----------|-------|--------------|-------|-----------------------|-------|
|       | A        | B     | A         | B     | A            | B     | A                     | B     |
|       | 23.86    | 24.65 | 27.37     | 26.32 | 26.50        | 26.50 | 26.50                 | 25.20 |
|       | 24.26    | 25.40 | 25.86     | 25.55 | 25.20        | 25.00 | 25.00                 | 25.60 |
|       | 24.26    | 24.45 | 25.32     | 26.17 | 26.00        | 25.50 | 26.00                 | 25.40 |
|       | 23.68    | 24.85 | 28.30     | 27.32 | 28.00        | 27.30 | 25.20                 | 25.00 |
| High  | 23.17    | 24.26 |           |       |              |       | 25.00                 | 25.00 |
|       | 24.78    | 24.19 |           |       |              |       | 23.50                 | 24.50 |
|       | 24.94    | 23.99 |           |       |              |       | 25.00                 | 25.50 |
|       | 23.47    | 24.11 |           |       |              |       | 24.00                 | 24.80 |
|       | 24.17    | 24.73 |           |       |              |       |                       |       |
|       | 24.25    | 23.63 |           |       |              |       |                       |       |
| Mean  | 24.08    | 24.42 | 26.71     | 26.34 | 26.43        | 26.07 | 25.02                 | 25.00 |
| S.D.  | ±.55     | ±.50  | ±1.37     | ±.73  | ±1.18        | ±1.03 | ±.96                  | ±.36  |

## APPENDIX

Table 3 (d) DRYING CURVES FOR THE OHAUS MOISTURE DETERMINATION BALANCE.

Moisture Percentage at 1 Minute Intervals at Several Wattage Levels.

|          |         | Heating Lamp at 1-1/4 Inch Mark |         |         |         |         |  |
|----------|---------|---------------------------------|---------|---------|---------|---------|--|
| Time in: | Water   | Ground:                         | Ground: | Ground: | Ground: | Ground: |  |
| Minutes: | 40W     | Beef:                           | Beef:   | Beef:   | Beef:   | Beef:   |  |
|          |         | 40W                             | 60W     | 80W     | 100W    | 140W    |  |
| 0        | : 0.00  | 0.00                            | 0.00    | 0.00    | 0.00    | 0.00    |  |
| 1        | : 1.00  | 0.60                            | 1.20    | 1.50    | 2.50    | 3.00    |  |
| 2        | : 3.00  | 3.00                            | 2.70    | 3.80    | 6.00    | 6.50    |  |
| 3        | : 6.00  | 5.00                            | 6.60    | 7.80    | 10.00   | 11.50   |  |
| 4        | : 9.00  | 9.00                            | 10.00   | 11.50   | 14.50   | 17.00   |  |
| 5        | : 12.00 | 12.00                           | 13.50   | 15.80   | 20.00   | 22.50   |  |
| 6        | : 17.00 | 15.00                           | 16.60   | 20.00   | 25.00   | 28.00   |  |
| 7        | : 21.00 | 18.00                           | 20.50   | 25.00   | 30.00   | 33.00   |  |
| 8        | : 25.00 |                                 | 24.50   | 29.50   | 34.80   | 38.00   |  |
| 9        | : 28.50 | 24.00                           | 27.50   | 34.50   | 39.50   | 42.00   |  |
| 10       | : 33.50 | 28.40                           | 31.50   | 38.50   | 43.50   | 46.00   |  |
| 11       | : 36.50 | 30.50                           | 34.80   | 42.50   | 47.00   | 49.00   |  |
| 12       | : 40.00 | 33.50                           | 37.00   | 46.00   | 50.50   | 52.50   |  |
| 13       | : 44.50 |                                 | 40.50   | 49.40   | 52.50   | 55.00   |  |
| 14       | : 47.00 | 38.80                           | 43.50   | 52.00   |         | 56.50   |  |
| 15       | : 51.50 | 41.50                           | 46.00   | 54.30   | 56.00   | 57.00   |  |
| 16       | : 56.50 | 44.00                           | 48.50   | 55.80   | 56.80   | 57.50   |  |
| 17       | : 59.50 | 46.30                           | 50.50   | 57.00   | 57.40   | 57.90   |  |
| 18       | : 63.00 | 48.00                           | 52.50   | 57.50   | 57.50   | 58.00   |  |

## APPENDIX

Table 3 (d) Continued.

|          |         | Heating Lamp at 1-1/4 Inch Mark |          |          |          |          |
|----------|---------|---------------------------------|----------|----------|----------|----------|
| Time in: | Water   | : Ground                        | : Ground | : Ground | : Ground | : Ground |
| Minutes: | 40W     | : Beef                          | : Beef   | : Beef   | : Beef   | : Beef   |
|          |         | : 40W                           | : 60W    | : 80W    | : 100W   | : 140W   |
| 19       | : 66.50 | 50.00                           | 54.00    | 57.90    | 57.80    | 58.20    |
| 20       | : 70.50 | 51.50                           | 55.50    | 58.00    | 58.00    | 58.50    |
| 21       | : 74.00 | 53.00                           | 56.00    | 58.20    | 58.20    | 58.70    |
| 22       | : 77.50 | 54.00                           | 56.50    | 58.50    | 58.30    | 58.70    |
| 23       | : 81.00 | 54.80                           | 56.80    | 58.50    | 58.40    |          |
| 24       | : 85.00 | 55.50                           | 57.00    | 58.50    | 58.50    |          |
| 25       | : 88.00 | 56.00                           | 57.30    | 58.60    | 58.50    |          |
| 26       | : 91.00 | 56.50                           | 57.50    | 58.60    | 58.50    |          |
| 27       | : 93.50 | 56.80                           | 57.50    | 58.80    | 58.50    |          |
| 28       | : 95.50 | 57.00                           | 57.50    | 58.80    | 58.50    |          |
| 29       | : 96.50 | 57.30                           | 57.50    | 58.80    |          |          |
| 30       | : 98.00 | 57.50                           | 57.60    | 58.90    |          |          |
| 31       | : 99.00 | 57.50                           | 57.70    | 58.90    |          |          |
| 32       | : 99.30 | 57.70                           | 57.70    | 59.00    |          |          |
| 33       | : 99.40 | 57.80                           | 57.20    | 59.00    |          |          |
| 34       | : 99.40 | 57.80                           | 57.80    | 59.00    |          |          |
| 35       | : 99.40 | 57.80                           | 57.80    | 59.00    |          |          |
| 36       | : 99.40 | 57.80                           | 57.80    |          |          |          |
| 37       | : 99.40 | 57.80                           | 57.90    |          |          |          |
| 38       | : 99.40 | 57.90                           | 58.00    |          |          |          |
| 39       | : 99.40 | 57.90                           | 58.00    |          |          |          |
| 40       | : 99.40 | 57.90                           | 58.00    |          |          |          |



## APPENDIX





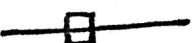
Table 3 (d) Continued.

|          |       | Heating Lamp at 1-1/4 Inch Mark |        |        |        |        |
|----------|-------|---------------------------------|--------|--------|--------|--------|
| Time in: | Water | Ground                          | Ground | Ground | Ground | Ground |
| Minutes: | 40W   | Beef                            | Beef   | Beef   | Beef   | Beef   |
|          |       | 40W                             | 60W    | 80W    | 100W   | 140W   |
| 41       | :     | 57.90                           | 58.00  |        |        |        |
| 42       | :     | 57.90                           | 58.10  |        |        |        |
| 43       | :     | 57.90                           | 58.10  |        |        |        |
| 44       | :     | 58.00                           | 58.10  |        |        |        |
| 45       | :     | 58.00                           | 58.10  |        |        |        |
| 46       | :     | 58.00                           | 58.10  |        |        |        |
| 47       | :     | 58.00                           | 58.10  |        |        |        |
| 48       | :     | 58.00                           | 58.10  |        |        |        |
| 49       | :     | 58.10                           | 58.20  |        |        |        |
| 50       | :     | 58.10                           | 58.20  |        |        |        |
| 51       | :     | 58.20                           | 58.20  |        |        |        |
| 52       | :     | 58.20                           | 58.20  |        |        |        |
| 53       | :     | 58.20                           | 58.20  |        |        |        |
| 54       | :     | 58.20                           | 58.20  |        |        |        |
| 55       | :     | 58.20                           | 58.20  |        |        |        |
| 56       | :     | 58.20                           | 58.20  |        |        |        |
| 57       | :     | 58.20                           | 58.20  |        |        |        |
| 58       | :     | 58.20                           | 58.20  |        |        |        |
| 59       | :     | 58.20                           | 58.20  |        |        |        |
| 60       | :     | 58.20                           | 58.20  |        |        |        |

EXPLANATION OF  
PLATE III

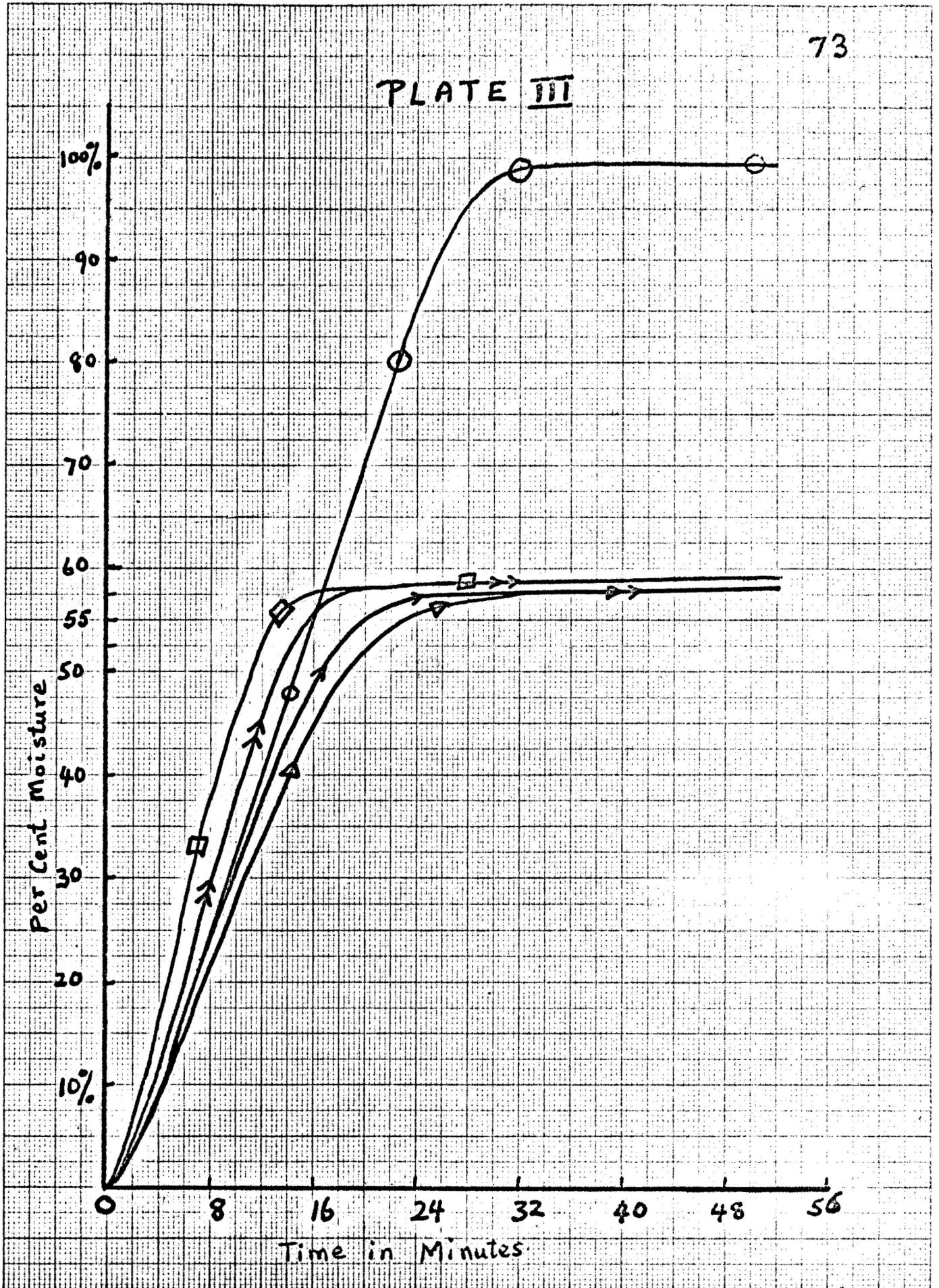
DRYING CURVES FOR THE OHAUS MOISTURE  
DETERMINATION BALANCE

See Data in Table 3 (d) in Appendix

-  = illustrates Drying Curve for Distilled Water at heater setting of 40W.
-  = illustrates Drying Curve for Ground Beef Sample at 40W heater setting.
-  = illustrates Drying Curve for Ground Beef Sample at 60W.
-  = illustrates Drying Curve for Ground Beef Sample at 80W heater setting.
-  = illustrates Drying Curve for Ground Beef Sample at 140W.

Drying curve for Ground Beef Sample at 100W heater setting not shown: it was too close to that at 140W heater setting to be shown clearly.

PLATE III



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RAPID ANALYTICAL METHODS FOR THE DETERMINATION OF  
FAT AND MOISTURE CONTENT OF  
GROUND MEATS

by

NASANI ERI MASABA

D. V. S. , Makerere University College, Kampala, Uganda, 1963.  
B. V. Sc. , University of East Africa, Nairobi, Kenya, 1964.

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Husbandry

KANSAS STATE UNIVERSITY  
Manhattan, Kansas

1968

Ground beef samples consisting of three levels of fat and moisture were prepared by mixing fresh beef shank meat and fat. Samples were prepared in two ways, namely by grinding and mixing three times or by mixing and blending in a Waring blender.

Ground beef containing 3% salt was also prepared to test effects upon Steinlite results. Ground beef samples were packed in "Whirl pak" bags and stored frozen until used. Two separate lots of pork sausage were sampled on the day of the test.

Three methods were employed to determine moisture content of ground beef and pork sausage samples using samples of four to six grams. The moisture determination balance method was compared with two air oven drying methods at 100°C for 16-18 hours. One oven drying method is an AOAC procedure involving use of crucibles and the other procedure involved use of paper thimbles. Pork sausage samples were similarly analyzed by all three methods.

Fat content determinations on ground beef samples of three fat levels, about 17%, 21%, 25% and prepared in two ways, were carried out by four methods of fat determination. The three rapid methods were: the Steinlite Electronic Fat Tester, modified Babcock using sulfuric acid and modified Babcock (Whalen) in which hydrochloric acid is used. The fourth method was the AOAC method of dry ether extraction using Soxhlet extractors. Pork sausage samples were subjected to the same methods.

Data were analyzed by analysis of variance as outlined by Snedecor (1956). If a significant variance ratio was found, Duncan's multiple range

test was used to locate the differences.

Moisture content determinations by the moisture determination balance were completed in forty minutes as compared to twenty-four hours with the oven drying methods. The lowest moisture values were obtained by the AOAC method (using crucibles) while the highest moisture values were obtained by the AOAC procedure using paper thimbles. The results obtained with the rapid moisture balance method more closely approached the results of the official method using paper thimbles than those where crucibles were employed. Method of sample preparation did not have a significant effect on the results. Results for moisture content with pork sausage samples were of similar pattern to those of ground beef samples. Each method differentiated between moisture levels consistently.

Fat content determinations by the three rapid methods were completed within thirty minutes as compared to over 50 hours for the AOAC method. The fat values obtained by the AOAC method on ground beef samples were the lowest and by the Steinlite method were the highest.

All the methods differentiated between the levels of fat consistently. At low and medium fat levels, modified Babcock results were close to the results obtained by the AOAC method, but the results obtained by the Steinlite and modified Babcock by Whalen were significantly higher than the AOAC results, the Steinlite registering the highest values. At the high fat level, the modified Babcock (Whalen) results were closest to the AOAC results although significantly higher.

Addition of 3% salt to ground beef samples caused a significant depression in the results obtained by the Steinlite. The method of sample preparation had no significant effect on the results of any fat method.

When pork sausage was analyzed for fat content by the same four methods, significant differences were noted between all methods. Lowest fat content results were obtained by the AOAC method with successively higher results by the Steinlite Electronic Fat Tester, modified Babcock and modified Babcock (Whalen) methods.