# HOW DIFFERENT OPERATING CONDITIONS OF FILTER PAPER PRESS METHOD AFFECT MEAT WATER HOLDING CAPACITY MEASUREMENT

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## Background

Water Holding Capacity (WHC) is the ability of meat to hold fully or in part its own water (Honikel, 1987) and it is influenced by the change in volume of myofibril (Offer and Knight, 1988). This qualitative parameter - affecting technological traits, sensory attributes and nutritional constituents - is of primary importance for the Meat Industry which has considerable pressing problems in this area and needs answers to assure firm quality. It is known that meat WHC is a result of metabolic events prior to harvest and slaughter and following the immediate *post mortem* conversion of the muscle to meat in relation to different factors.
Present methods available to measure the WHC of meat and its products (Honikel, 1987; Trout, 1988; Barton-Gade *et al.*, 1993), despite many efforts over the years, do not have a sufficient standardization, essential for comparison (Honikel, 1998). It has been particularly observed that the application of Filter Paper Press Method (Grau and Hamm, 1957) - which requires the compression of a little amount of meat on filter paper, the subsequent determination of the surfaces formed by meat and juice and the estimation of the difference between the areas - has been suffering a lot of interpretations and adaptations. Some Authors (Irie *et al.*, 1996; Onega *et al.*, 2000; Fiems *et al.*, 2003) utilized different filter paper types and amounts of meat; when considering the load, they put it under different pressures and compression times; sometimes they measured surfaces with the aid of a planimeter, at times outlining areas on the original by pencil, or by the use of an optical electronic system (Video Image Analyzer). Finally, Authors even applied different formulae to measure WHC (Wierbicki and Deatherage, 1958; Hofmann *et al.*, 1982; Van Oeckel *et al.*, 1999).
It was necessary to verify if investigations carried out according to different adaptations of Filter Paper Press Method could be directly comparable.

## Objectives

The purpose of this study is to verify if different operating conditions (applied load, filter paper type and length of compression) could influence the results in the Water Holding Capacity measurements by Filter Paper Press Method thus hindering the comparing of data coming from different researches.

## Materials and methods

The Filter Paper Press Method of Grau and Hamm (1957) for measuring WHC was adopted, but the procedure (load, time and surface measurement) was automated by using an instrument (BT-WHCi) that applies Video Image Analysis (VIA) to area measurement (Barbera, 2003). Water Holding Capacity was investigated on samples of different meats (beef, chicken and pork) obtainable on the market. Experimental data was gathered from the analysis of beef *M. longissimus thoracis et lumborum*, chicken *M. pectoralis major* and pork *M. longissimus dorsi*. The meat, chilled at 4°C and freed from external fat and connective tissue, was rapidly homogenised (Braun Multiquicksystem ZK100) for 10 seconds. A sample of 250 mg of homogenised meat was placed on a filter paper and compressed between two plexiglass sheets. Filter paper was dried in the oven at 105°C and maintained in a dryer until the analysis started. The meat and the liquid areas ($mm^2$) were measured by VIA, every minute for ten minutes.
Water release was measured in different conditions, referring to the following factors: load applied to compress the meat (294.2, 490.3 and 588.4 N); filter paper type - Whatman 1 (W1) and 42 (W42); animal type to test effectiveness of BT-WHCi, using three animals for each type.
The data were analysed using the SAS 8.2 package. Factorial analysis of covariance for each minute was performed on the three factors and meat sample weight as covariate. The dependent variables obtained were:

- **TAn** ($mm^2$) — Total Area, n=0 to 10 min;
- **M/Tn** (%) = Meat Area / TAn*100 — Ratio, n=1 to 10 min (Hoffman *et al.*, 1982);
- **LAn** ($mm^2$) = TAn - Meat Area — Liquid Area, n=1 to 10 min;

- **FWn** (mg of $H_2O$) = (LAn / 9.48) – 8 Free Water, n=1 to 10 min (Grau and Hamm, 1957).

These dependent variables are an example of a few different ways to express the Water Holding Capacity found in the quoted bibliography.

## Results and discussion

A three-factor main effects model (load, filter paper and animal type) and meat sample weight as covariate, was used because interactions among main factors were not statistically significant. The problem to measure the particularly pale meat of pork and the even paler chicken meat was overcome changing the BT-WHCi light threshold (Fig. 1). The covariate (meat sample weight: 250.6±2.9 mg) was not significant, indicating a homogeneous sample preparation. The compression time effect was not submitted to statistic analysis, since the measurement is usually taken at a fixed time, but the increasing trend is clearly evident (Table 1). The loads were respected and variability was kept low: 294.4±2.7, 491.8±2.0 and 584.7±6.2 N. The dependent variable mean data are reported in Table 1, while animal type data were only partially reported in the text.

Total Area

The load effect was always significant and a higher load corresponded to a higher TA. No paper filter effect appeared until the 7th min; TA was significantly higher in W42 between 8th and 10th min. The increasing trend in time observed in TA indicated still available free water beyond the 10th min at 588.4 N load. Significant differences among animal types appeared at all minutes. Values were lower in pork and higher in beef. At the 5th min, Total Areas were: 1234, 1319 and 1397 $mm^2$ respectively for pork, chicken and beef. A different order was found for the Meat Area (Time 0') that was: beef, pork and chicken (678, 723 and 865 $mm^2$).

Meat Area / Total Area

The load effect started at the 5th min; M/T grew as the load increased. No effect was ascribed to the filter paper. Decreasing trend in time confirmed the presence of free water still available beyond the 10th min. M/T was significantly different among animal types throughout the ten minutes. Values were lower in beef and higher in chicken meat. The percentages at the 5th min were: 48.4, 59.2 and 65.6% respectively for beef, pork and chicken.

Liquid Area

The load effect appeared at the first min until the 7th min; values were higher with higher load. After the 7th min, no significant differences were seen in LA, though always positively correlated with load. The filter paper effect started at the 7th min with values significantly higher in W42. LA was significantly different among animal types throughout the total elapsed time. Chicken meat had the lowest values and beef the highest ones. The values at the 5th min were: 454, 511 and 720 $mm^2$ respectively for pork, chicken and beef.

Free Water

FW is a formula based on LA, consequently the effects of the load, the filter paper and the time were the same already observed in Liquid Area. Also FW showed significant differences among animal types throughout the ten minutes. In this case chicken had the lowest values and beef the highest ones. The values at the 5th min were: 39.9, 45.9 and 67.9 mg $H_2O$ for chicken, pork ad beef, equivalent respectively to 16, 18 and 27% of Free Water.

These results confirm that load and paper filter significantly influence WHC values. Different applications of Grau and Hamm's method do not allow to ensure comparable data from researches. Moreover the way of the area measurement must be considered as an important source of variability (planimeter, outlining or not, VIA) which has been solved in this research. Finally, diverse formulae to express WHC complicate comparison, do not highlight considered factor effects and lead to different conclusions, such as evinced by M/T, TA, LA and FW.

## Conclusions

The Filter Paper Press Method has the advantage to be rapid and simple but a proper standardisation is necessary. The obtained results clearly show that WHC values depend on: applied load, filter paper type, compression time, area measurement method and the dependent variable used to express it.

In this research all these factors have been kept under control so that it will be possible to define and standardize a set of working conditions and to automate it in a reliable way.

The application to different animal types, in particular chicken, shows that BT-WHCi also works under very difficult light conditions and last but not least, results can be directly comparable.

Many methods and different operating conditions of Filter Paper Press Method have been published in literature causing confusion to interpret data in this field. Now it will be possible to reassess the Filter Paper Press Method and to define the most useful operating conditions for it.
In this way an instrumental technique for rapid screening can be used to measure the meat Water Holding Capacity and improve meat quality control which is of great importance to the Industry and the Consumers.

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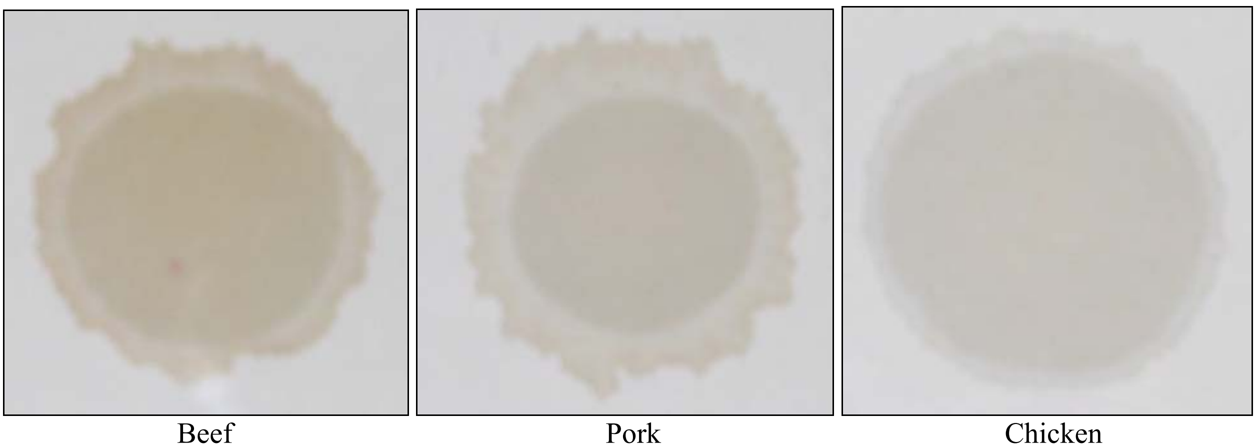


**Figure 1**. Different hues in beef, pork and chicken on filter paper (Whatman 1).

**Table 1**. Dependent variable mean values (EDF=155).

| Time | Load (N) | | | Filter paper | | EMS |
|---|---|---|---|---|---|---|
| (min) | 294.2 | 490.3 | 588.4 | W1 | W42 | |
| Total Area (mm$^2$) | | | | | | |
| 0 | 686$^{A}$ | 758$^{B}$ | 822$^{C}$ | 755 | 754 | 2854 |
| 1 | 946$^{A}$ | 1049$^{B}$ | 1119$^{C}$ | 1052 | 1024 | 10899 |
| 2 | 1049$^{A}$ | 1155$^{B}$ | 1223$^{C}$ | 1151 | 1134 | 10684 |
| 3 | 1119$^{A}$ | 1229$^{B}$ | 1303$^{C}$ | 1219 | 1215 | 10202 |
| 4 | 1174$^{A}$ | 1285$^{B}$ | 1360$^{C}$ | 1271 | 1275 | 9695 |
| 5 | 1220$^{A}$ | 1329$^{B}$ | 1401$^{C}$ | 1309 | 1324 | 9551 |
| 6 | 1257$^{A}$ | 1365$^{B}$ | 1437$^{C}$ | 1344 | 1363 | 8969 |
| 7 | 1287$^{A}$ | 1393$^{B}$ | 1462$^{C}$ | 1368 | 1393 | 9087 |
| 8 | 1318$^{A}$ | 1417$^{B}$ | 1486$^{C}$ | 1393$^{a}$ | 1422$^{b}$ | 8204 |
| 9 | 1342$^{A}$ | 1437$^{B}$ | 1503$^{C}$ | 1411$^{a}$ | 1444$^{b}$ | 7924 |
| 10 | 1362$^{A}$ | 1453$^{B}$ | 1517$^{C}$ | 1426$^{a}$ | 1462$^{b}$ | 7622 |
| Meat Area / Total Area (%) | | | | | | |
| 1 | 73.8 | 73.4 | 74.4 | 72.8 | 75.0 | 66 |
| 2 | 66.3 | 66.4 | 68.0 | 66.2 | 67.6 | 49 |
| 3 | 62.0 | 62.2 | 63.6 | 62.4 | 62.9 | 37 |
| 4 | 59.0 | 59.4 | 60.9 | 59.7 | 59.8 | 30 |
| 5 | 56.7$^{A}$ | 57.4 | 59.1$^{B}$ | 58.0 | 57.5 | 26 |
| 6 | 55.0$^{A}$ | 55.8 | 57.5$^{B}$ | 56.4 | 55.9 | 23 |
| 7 | 53.7$^{A}$ | 54.7$^{a}$ | 56.6$^{Bb}$ | 55.4 | 54.6 | 22 |
| 8 | 52.3$^{A}$ | 53.7$^{a}$ | 55.6$^{Aa}$ | 54.3 | 53.5 | 20 |
| 9 | 51.4$^{aA}$ | 53.0$^{b}$ | 55.0$^{cB}$ | 53.6 | 52.6 | 19 |
| 10 | 50.6$^{aA}$ | 52.3$^{b}$ | 54.5$^{cB}$ | 53.0 | 52.0 | 18 |
| Liquid Area (mm$^2$) | | | | | | |
| 1 | 260$^{a}$ | 291 | 297$^{b}$ | 296 | 269 | 9706 |
| 2 | 363$^{a}$ | 398 | 401$^{b}$ | 395 | 379 | 10019 |
| 3 | 433$^{a}$ | 471$^{b}$ | 482$^{b}$ | 464 | 460 | 9474 |
| 4 | 488$^{aA}$ | 527$^{b}$ | 538$^{B}$ | 515 | 521 | 9011 |
| 5 | 534$^{a}$ | 571$^{b}$ | 579$^{b}$ | 553 | 570 | 9000 |
| 6 | 572$^{a}$ | 607$^{b}$ | 616$^{b}$ | 589 | 608 | 8587 |
| 7 | 601$^{a}$ | 636$^{b}$ | 640$^{b}$ | 613$^{a}$ | 639$^{b}$ | 8797 |
| 8 | 632 | 659 | 664 | 637$^{a}$ | 667$^{b}$ | 8207 |
| 9 | 657 | 679 | 682 | 656$^{a}$ | 689$^{b}$ | 8129 |
| 10 | 677 | 696 | 695 | 671$^{a}$ | 707$^{b}$ | 8017 |
| Free Water (mg of $H_2O$) | | | | | | |
| 1 | 19.4$^{a}$ | 22.7 | 23.3$^{b}$ | 23.3 | 20.4 | 108.0 |
| 2 | 30.3$^{a}$ | 33.9$^{b}$ | 34.4$^{b}$ | 33.7 | 32.0 | 111.5 |
| 3 | 37.7$^{a}$ | 41.7$^{b}$ | 42.8$^{b}$ | 40.9 | 40.5 | 105.4 |
| 4 | 43.5$^{aA}$ | 47.6$^{b}$ | 48.8$^{B}$ | 46.3 | 47.0 | 100.3 |
| 5 | 48.4$^{a}$ | 52.2$^{b}$ | 53.1$^{b}$ | 50.4 | 52.1 | 100.1 |
| 6 | 52.3$^{a}$ | 56.1$^{b}$ | 57.0$^{b}$ | 54.1 | 56.1 | 95.5 |
| 7 | 55.4$^{a}$ | 59.1$^{b}$ | 59.6$^{b}$ | 56.6$^{a}$ | 59.4$^{b}$ | 97.9 |
| 8 | 58.7$^{a}$ | 61.5 | 62.1$^{b}$ | 59.2$^{a}$ | 62.4$^{b}$ | 91.3 |
| 9 | 61.3 | 63.7 | 63.9 | 61.2$^{a}$ | 64.7$^{b}$ | 90.4 |
| 10 | 63.4 | 65.4 | 65.3 | 62.8$^{a}$ | 66.6$^{b}$ | 89.2 |

A B C = $P<0.01$; a b c = $P<0.05$