TEST CONDITIONS FOR MEASURING WATER HOLDING CAPACITY OF BEEF PRODUCTS

G.S. MITTAL, M. ZHANG and S. BARBUT

School of Engineering, and Dept. of Animal Science, University of Guelph, Guelph, Ontario, Canada

Summary: The effects of various test conditions for measuring water holding capacity (WHC) by press and centrifugal methods of ground beef were reported. In centrifugal method, WHC increased with the increase in rpm and salt concentration, and decrease in test temperature. Recommended test conditions are 7500 rpm, 15 min and 2 to 10°C test temperature. In press method, WHC increased with the increase in applied force and test duration, and increase in sample size and salt concentration up to 2%. Recommended test conditions are 1 g sample size, 2 to 3 min test duration and 10 to 30 kN force.

Introduction: WHC contributes to tenderness, colour, flavour and the overall notion of "quality of meat". Loss of fluid during storage and processing is concerned by meat producers, processors and consumers and it is related with WHC. Therefore, the measurement of WHC is important for meat quality studies. Various methods for measuring WHC have been developed and improved (Honikel, 1987; Trout, 1988; Wierbicki and Deatherage, 1958; Kauffman et al., 1986). To measure WHC, force is applied to remove unbound or loosely bound water. The applied force may be produced by either centrifugation (Wierbicki and Deatherage, 1958; Bouton et al., 1972), or compression (Honikel, 1987). The press method was one of the first methods developed to measure WHC. With this method, the unbound water is quantitatively removed from the sample by pressing a small sample between two filter papers. The amount of water released from the sample is measured either directly by weighing the filter papers or indirectly by measuring the area of filter wetted relative to the area of pressed sample. In the centrifugal method, a centrifugal force is applied on the meat sample to remove the loosely bound water (Bouton et al., 1972). The amount of water released was determined either directly by weighing the amount of water released or indirectly by weighing the sample after centrifugation. In fact, this method differs from the press method.

Materials and methods: Factorial experimental design was used. Five replications for press method and four for centrifugal method were conducted. The lean beef muscle was ground with a chopper at medium speed for 30 s. The ground meat samples in bags were placed in a blast freezer to freeze at -17°C for at least 24 h. Whenever required the meat was taken out from frozen room and put into the chilling room at 2°C for 48 h and then mixed with a mixer (Braun AG. Frank furi/M, Type 4243, Germany) for one minute. The samples with three different salt concentrations--0%, 1% and 2%, were tested. Salt was dissolved in the distilled water weighing 5% of meat. The salt solutions were mixed with the meat samples. The samples were incubated at 2°C for 1 h before test. In press method, various sample's masses (0.5, 1 or 1.5) with different salt concentrations were placed between two filter papers of 11 and 15 cm diameters, and pressed by a press (Model C, Fred Carver Inc., Summit, NJ) using a pressure of 10, 20 or 30 kN for 1, 2 or 3 min. The experiment consisting of 81 treatments (3 salt concentration, 3 pressure, 3 time and 3 sample mass). The experiment was replicated four times, and a completely randomized factorial design was used.

For centrifugal method, the following test parameters were selected: three centrifugal speeds--2500, 7500 and 15000 rpm; three salt concentrations--0 M, 0.3 M and 0.6 M, three test durations--7.5 min, 15 min and 22.5 min, and three different test temperatures--2°C, 10°C and 20°C. Nine batches of samples were tested. Fifteen test tubes were used in each batch. Each tube was filled with 5 g well mixed meat. One of the three solutions was introduced into each five of 15 tubes. One of the nine combinations of test temperature and duration was chosen for each batch. The samples were incubated in the tubes at chosen temperature for 1 h. There were 81 treatments and experiment was replicated 5 times. The experiments were conducted on a Centrifuge (model J2-21, Spinco Division of Beckman Instruments Inc., Palo Alto, CA). The centrifugal field force was 959 G at 2500 rpm, 8630 G at 7500 rpm, and 30100 G at 15000 rpm. Moisture content was measured by an oven method. 5 g sample was placed in an oven (model 28, Precision Scientific) at 60°C for 12 h. Fat, ash and protein were determined by AOAC (1990) methods.

With the press method, the ability of meat to hold its own water is measured. This was calculated by the following equation given by Min and Ni (1989):

$$B=(1-F)=1-\frac{a-b}{M}*2*C$$

Where, B = bound water, F = free water, a = wet area on filter paper (mm^2), b = meat film area on the filter paper (with compression, the meat sample is pressed into a thin film) (mm^2), M = total water content in the sample meat, C = the water filter paper can absorb in unit area (8.24×10^{-5} g/mm^2).

Results and discussion: Centrifugal method: The average composition of ground beef was 71.8% water, 23.1% protein, 0.3% fat and 1.0% ash. ANOVA shows that all the test parameters affected WHC significantly ($P<0.0001$). Centrifugal force affected WHC to a large extent compare to other parameters, it contributed > 80% to the S.S. of model. Two term interactions (time*temp, time*force, salt*force and temp*force) and three term interaction (time*temp*force) also affected WHC significantly. Table 1 provides the Duncan's multiple range test results. At 15000 rpm, WHC was negative for all treatments. It ranged from -24.72% at 20°C, 15 min test duration and no salt solution to -10.19% at 2°C, 7.5 min test duration and 0.6 M solution. At 2500 rpm, WHC was positive which changed from 12.52% at 20°C, 15 min and 0 M solution to 39.54% at 2°C, 22.5 min test duration and 0.6 M solution. WHC changed from -12.4% at 20°C, 22.5 min test duration and 0 M to 25.82% at 2°C, 7.5 min test duration and 0.6 M at 7500 rpm.

The Duncan's multiple test results of overall average WHC show that it decreased with the increase of test duration from 7.5 to 15 min. WHC also decreased with the increase in test temperature or rpm, or decrease in salt concentration. ANOVA of WHC at 2500 rpm showed that salt concentration and temperature affected WHC significantly at 0.01% level, while test duration affected WHC at 0.91% level. While the interaction of time and temperature affected WHC at 1.82% level. Duncan's results showed that with the increase in time from 7.5 to 15.0 min or 15.0 to 22.5 min, or with the increase in temperature from 2 to 10°C, WHC did not show significant differences. The ANOVA for WHC at 7500 rpm showed that the test temperature had the largest effect on WHC and salt concentration the smallest. The interaction of test time and temperature also had the significant effect. Duncan's results were similar to previous treatments at 15000 rpm. At 15000 rpm, the salt concentration had the largest influence on WHC based on ANOVA, while the effect of test duration was the smallest. The interaction of test duration and temperature had significant effect on WHC. The Duncan's results were similar to the results obtained for overall WHC.

When the centrifugal force is applied on the meat sample, the myofibril may or may not shrink depending on how large the force is. At 15000 rpm centrifugation, the water retaining ability of the meat was negative (Table 1). This means that not only the absorbed water was expelled, some of the initial water of the meat was also expelled. This may be due to the shrinking of the myofibril at this force. At the constant force, as the salt concentration increased, WHC increased. Thus, the salt solution seems also to increase the strength of the myofibril besides expanding the myofibrilla. The higher the salt concentration, the stronger the myofibrilla. As the test temperature increased, WHC decreased at the constant applied force. This may be due to the softening of myofibril with the increase in temperature or decrease in the ability of the salt solution to depolymerising of thick filament with the increase in temperature. Since the effect of temperature was also significant on the meat samples without salt solution, the first reason seems to be valid. At 15000 rpm, WHC also increased with the increase in test duration. The longer the force was applied on the sample, more water was expelled from the myofibril up to 15 min duration. At 7500 rpm, both negative and positive values of WHC were observed. This may be due to the shrinking or expansion of the myofibrilla. Thus, as the temperature increases, the strength of lattices of myofibril reduced. 15 min test duration at 2°C appears to be suitable test conditions.

Based on above mentioned results and discussion, the following conclusions are derived: (i) Test rpm provides significant effects on WHC. At higher rpm, water is expelled from the meat, while at lower rpm, water is retained. (ii) Salt in the meat increases WHC by expanding the myofibril and increasing the strength of its lattices. (iii) Increase in temperature decreases the strength of the lattices of myofibrilla of meat. This results in lower WHC at the same rpm. (iv) Recommended test conditions are 7500 rpm, 15 min and 2 to 10°C test temperature. (v) When the applied rpm is smaller than the myofibril strength limit, its structure will not change while above this limit, the myofibril will shrink.

Press method: ANOVA results show that sample size and salt concentration had the largest effect on WHC. However, all the factors including the interactions of the factors had significant effects. Table 2 shows the Duncan's multiple range test results. The smallest WHC was 0% corresponding to the test conditions of 0% salt concentration, 30 kN force, 0.5 g sample size and 3 min test duration, while at the test conditions of 2% salt concentration, 10 Kn force, 1.5 g sample and 1 min test duration, the highest WHC of 64.04% was observed. All the treatments had significant effect on WHC. WHC increased with the increase of the sample size and salt concentration, and with the decrease of applied force and test time. Similar results were obtained when Duncan's test was conducted for the data sorted on the basis of sample mass.

ANOVA of WHC for the sample size of 0.5 g showed that all the factors including the interactions of the factors had the significant effect at ≤0.9% level. The Duncan's results are similar to average WHC for all the combined treatments. For 1% salt concentration for 0.5 g sample, WHC results indicate that the effect of test duration was different at other concentrations. As the test duration increased from 1 to 2 min WHC decreased, but as the test duration further increased to 3 min WHC increased, and this trend further amplified with the increase of the applied force. At 3 min test duration, WHC of 1% salt concentration was bigger than that of 2% concentration and this difference further increased with the increase in applied force. Overall, WHC increases with the increase in applied force and test duration, and increase in sample size and salt concentration up to 2%. Recommended test conditions are: 1 g sample size, 2 to 3 min test duration and 10 kN to 30 kN force.

References:

AOAC, 1990. "Official methods of analysis", Assoc. Official Analytical Chemists, Washington, D.C.

Bouton, P.E., Harris, P.V., Shorthose, W.R., 1972. The effects of ultimate pH on ovine muscle: water holding capacity. J. Food Sci., 37, 351-355.

Honikel, K.O., 1987. critical evaluation of methods detecting water holding capacity in meat. In: "Accelerated processing of meat" (A. Romita, C. Valin, A.A. Taylor, eds.), Elsevier, New York.

Kauffman, R.G., Eikelenboom, G., Van der Wal, P.G., 1986. A comparison of methods to estimate water holding capacity in postrigor porcine muscle. Meat Sci., 18, 307-322.

Min, L., Ni, C., 1989. Research in improving the water holding capacity of meat in sausage products. Proc. 35th international Congress of Meat Sci. Technol., 781-786pp.

Trout, G.R., 1988. Techniques for measuring water binding capacity in muscle foods--a review of methodology. Meat Sci., 23, 235-252.

Wierbicki, E., Deatherage, F.E., 1958. Determination of water holding capacity in fresh meats. J. Agric. Food Chem., 6, 387.

Table 1. Duncan's multiple range test results for WHC by centrifugal method

Test conditions	Mean value of WHC, %			
	Overall	Centrifugal speed		
		2500 rpm	7500 rpm	15000 rpm
Test time, min				
7.5	4.0 a	23.0 a	4.1 a	-15.6 a
15	1.1 b	24.0 a b	-3.6 b	-17.9 b
22.5	1.2 b	26.0 b	-4.8 b	-18.5 b
Test temperature, °C				
2	6.5 a	28.0 a	5.9 a	-14.9 a
10	1.8 b	26.0 a	-3.3 b	-17.9 b
20	-1.9 c	20.0 b	-7.1 c	-19.2 c
Salt concentration, M				
0	-2.2 c	19.0 c	-4.7 c	-21.2 c
0.3	1.9 b	25.0 b	-1.8 b	-17.6 b
0.6	6.6 a	31.0 a	2.1 a	-13.2 a
RPM				
2500	25.2 a	--	--	--
7500	-1.5 b	--	--	--
15000	-17.4 c	--	--	--

Data followed by the same letter in a column are not significantly different at 95% level.

Table 2. Duncan's multiple range test results for WHC by press method

Test conditions	Mean value of WHC %			
	Overall	Sample mass g		
		0.5	1.0	1.5
Test time, min				
1	0.41 a	0.32 a	0.40 a	0.52 a
2	0.33 b	0.20 b	0.35 b	0.46 b
3	0.28 c	0.18 c	0.27 c	0.40 c
Applied force, kN				
10	0.43 a	0.38 a	0.41 a	0.51 a
20	0.33 b	0.22 b	0.32 b	0.46 b
30	0.26 c	0.10 c	0.29 c	0.42 c
Salt concentration, %				
0	0.22 c	0.09 c	0.21 c	0.35 c
1	0.37 b	0.28 b	0.37 b	0.49 b
2	0.44 a	0.32 a	0.45 a	0.54 a
Sample mass, g				
0.5	0.23 c	--	--	--
1.0	0.33 b	--	--	--
1.5	0.46 a	--	--	--

Data followed by the same letter in a column are not significantly different at 95% level.