A NOVEL NONINVASIVE METHOD OF FAT MEASUREMENT

C.M. BARTLE[1] AND B.B. CHRYSTALL[2]

DSIR Nuclear Sciences Group, Wellington, NZ[1] and MIRINZ., Hamilton. NZ[2].

SUMMARY:

This paper describes a new novel noninvasive system to measure the fat contnt in cartons of boneless meat. The system using the simultaneous transmission of neutrons and gammaa rays provides an accurate, rapid assessment of the fat co9ntent that is not influenced by the meat temperature, the piece size or carton geometry.

INTRODUCTION:

Much of New Zealand's beef and a proportion of its sheepmeats are sold frozen in standard 27.2 kg cartons for manufacturing purposes. Therefore, it is not surprising that the product is sold on a specified fat content. At present there is no completely satisfactory on-line method for assessing the composition of cartoned meat. Typically, fat content is assessed visually and adjusted by the packers in the boning rooms. The chemical lean (CL) is assessed by coring a statistically selected number of cartons (Baxter 1971). The cores are then analyzed by a variety of methods, ranging from solvent extraction to microwave drying. (Chrystall 1990).

Nondestructive methods are desirable but are not commonly available. Pulsed ultrasound and NMR (nuclear magnetic resonance) have been suggested, but neither has been developed into commercial instruments. There are commercial systems available that have been classed as on-line instruments. For example, the MQ25 (a derivation from the EMME system), manufactured by Dickey John Corporation, Illinois, can assess the content of cartons of meat as they pass along a conveyor belt. Unfortunately, the results are highly temperature dependent and are also dependent on the size of meat pieces within the carton with accuracy increased as the size of pieces decrease. The instrument has recently been evaluated by Eustace et al. 1989. Another instrument that is considered to be capable of assessing the composition on-line is the Glafascan. (Glafascan Ltd, Cambridge) (Anon. 1981). This device uses video imaging of the product on a conveyor to assess the visual proportions of fat and lean, to determine the composition. As with the MQ25 the accuracy increases as the size of the pieces decreases. The thickness of the sample on the conveyor also affects the accuracy, since the instrument only sees the surface.

A recent new approach assessing the meat volume and using the established density difference between lean and fat has been described by Davey (1991) and tested by Davey and Lovatt (1991). The prototype instrument appears to show promise being unaffected by temperature over the range tested (8.7°C to 15.7°C) but shows sensitivity to piece size, being more accurate with larger pieces..

The method discussed in this paper uses a completely different principle, which results in an instrument that can accurately measure the fat content in cartons. The results are unaffected by temperature in the range tested -18°C to +20°C, and by piece size in the carton, mince to large pieces.

METHOD : The new method depends on the simultaneous transmission of neutrons and gamma rays (NEUGAT technique) through a carton of meat. The method is insensitive to the distribution of fat throughout the product and to the thickness of the meat.

Equipment : The prototype instrument consists of three principal elements, as shown in Figure 1. The first element is the top tank, in which the radiation source can be moved vertically in a central tube. The tank is filled with water to shield the operator from the radiation source ^{252}Cf (Californium 252). The second element of the system is another large tank housing the radiation detectors. This tank is also filled with water, both as a radiation shield and as a means of controlling the temperature of the detectors. The data from the detectors are processed by an on-line computer system. The third element is a conveyor system that moves the cartons of meat under the source and over the detector array.The relative position of the source, meat cartons and the detectors is shown in Figure 2.

Theory: When a neutron or gamma beam is passed through a carton of meat the radiation is reduced according to the expression

$$I = I_o \exp[-\mu_f M_f - \mu_m M_m)] \quad (1)$$

where μ_f and μ_m are constants and M_f and M_m are the masses per unit area of fat and lean tissue respectively.

I is the amount of radiation passing through the meat and I_o the incident radiation.

The fat fraction is given by $$w = \frac{M_f}{M_f + M_m} \quad (2)$$

and the product density by $$\rho = \frac{M_f + M_m}{Thickness} \quad (3)$$

The approach has been used to measure water in a variety of materials (Bartle et al. 1990). In contrast with those materials the fat and lean tissues both have high hydrogen concentrations. The neutron mass attenuation coefficient is highest for fat even though lean meat is 75% water.

RESULTS : In the first instance, blocks of beef lean and fat with compositions from 1 to 70% chemical fat by weight, as determined by the soxhlett method (AOAC 1984) were used to calibrate the apparatus. These blocks were made so that nine fitted into a standard 27.2 kg meat carton in three layers. Subsequently, whole cartons of meat have been used.

The calibration of the instrument with the meat blocks is shown in Figure 3. The (μ) coefficients obtained from a least squares fit were:

μ_{nf} (neutron coefficient for fat) $= 1.51 \times 10^{-2}\ m^2kg^{-1}$ μ_{nm} (neutron coefficient for meat) $= 1.17 \times 10^{-2}\ m^2kg\text{-}1$

$\mu_{\gamma f}$ (γ coefficient for fat) $= 3.97 \times 10^{-3}\ m^2kg^{-1}$ $\mu_{\gamma m}$ (γ coefficient for meat) $= 3.47 \times 10^{-3}\ m^2kg^{-1}$

A similar calibration test with mutton blocks yielded very similar coefficients. The thickness of the meat cartons is about optimal for measurements using neutrons in terms of minimizing the error in a given time. The present apparatus can measure the percentage fat in a box to about 1.5% (SD) in 1 minute.

The dose delivered to each carton was typically 0.01mG. This level is 5×10^4 times lowere than that accepted by most countries as negligible in industry (500mG), and 10^9 lower than doses used to sterilize food by irradiation and is accepted as not detectable and safe by WHO. Calculations show that immediately after measurement the activity in the meat due to neutron capture on ^{23}Na is 5×10^3 smaller than the ^{40}K activity naturally present in meat. The sodium activity has a half-life of 15 h and disappears in a few days.

Field trials involving several hundred cartons of boneless manufacturing meat with a range of specified fat levels were undertaken in a large meat processing plant. In one test 36 cartons of nominal fat contents of 15 and 20% were analyzed in pairs using NEUGAT on the whole boxes and Babcock chemical test (Koniecko, 1979) on core samples. Analysis on each pair took 2 minutes in the NEUGAT and 30 minutes by the chemical method. The average fat value differed by only 0.2% and the standard deviation was 2.2% over the 36 cartons. Sample cartons have been measured immediately after packing, and again after having been frozen or minced and frozen. The results of the measurements made at the different product temperatures and in the different forms did not vary significantly.

Improvements made since the prototype trials promises to allow measurement times in the order of 5-10 seconds per carton without loss of accuracy. The prototype development is being extended to commercial manufacture by AWA (NZ) Ltd.

CONCLUSIONS:

The benefits of the NEUGAT system over other methods are:

Speed:	The measurement time will be in the order of 10 seconds per carton.
Meat fraction tested:	The prototype assessed the influence of 50% of the meat in the carton. A higher fraction could be measured by a geometry change and use of more than one source.
NonInvasiveness:	The measurements are nondestructive and the contents of the box are not disturbed.
Flexibility:	Measurement could take place on-line in the boning room or anywhere required.
Accuracy:	Measurement system is insensitive to box geometry, product form and temperature. Results are accurate to 1.5%.

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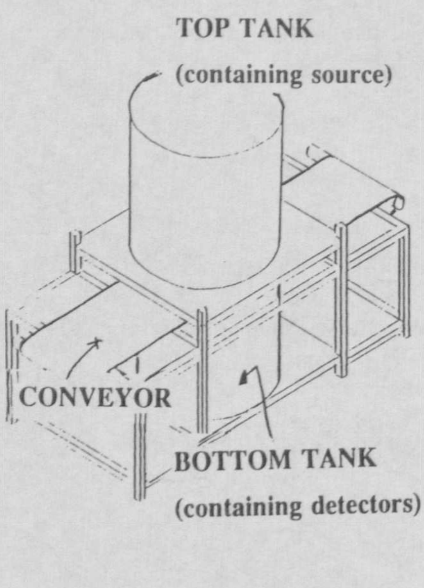

Figure 1. Prototype fat measuring machine

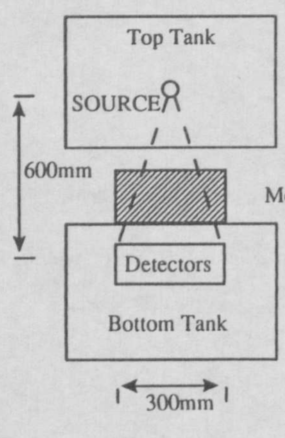

Figure 2. Relative positions of source meat carton and detectors

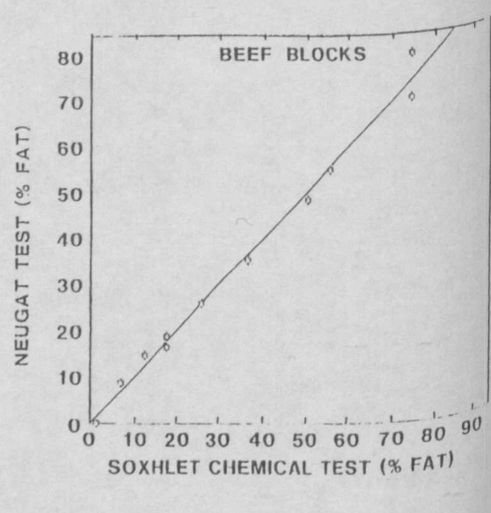

Figure 3.Fat values by Neugat and Soxhlet.