Elektrische Leitfähigkeit; ein Fleischqualitätskriterium?

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Durch die Messung der elektrischen Leitfähigkeit in Fleisch bei zwei Frequenzen (5 KHz und 100 KHz) kann ein Impedanz-Verhältnis(Z-Wert) berechnet worden. Dieser Z-Wert ist sowohl in Schweinefleisch als auch in Rindfleisch kurz nach der Tötung der Tiere hoch (> 1,10). Dieser Wert sinkt darauf bis unter 1,10. Die Senkung steht im Zusammenhang mit der Länge des Zeitraumes zwischen der Schlachtung und des Momentes der Impedanz-Messung. Der Prozess verläuft schneller in Schweinefleisch als in Rindfleisch. Fleisch mit einem hohen Z-Wert gibt nach Einfrieren und darauffolgendem Auftauen Z-Werte, die kleiner sind als 1,10. Die Bestimmung des Z-Wertes könnte eine Anweisung über das Mürbewerden des Fleisches geben.

Electrical conductivity; a meat quality criterion?

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An impedance ratio(Z-value) in meat can be calculated by measuring the electrical conductivity at two frequencies (5 KHz and 100 KHz). This Z-value is high (> 1.10) shortly after slaughter in both pork and beef. This is followed by a decrease in the Z-value to below 1.10. The decrease is related to the time lapse between slaughter and the moment that the impedance measurement is made. The decrease in Z-value is more rapid in pork than in beef. Freezing and thawing results in a Z-value below 1.10 in meat that had a Z-value greater than 1.10 initially. The estimation of the Z-value in meat may provide an indication of the meat's maturity.

La conductance électrique; un critère de la qualité de la viande?

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En mesurant la conductance électrique de la viande à deux fréquences (5 KHz et 100 KHz) on peut calculer le rapport des impédances (valeur-Z). Pendant un temps bref après l'abattage la valeur-Z est élevée (> 1,10) dans les viandes porcines et bovines. La valeur-Z diminue ensuite au-dessous de 1,10. Cette diminution est relatée avec la période qui s'écoule entre l'abattage et la mesurage de l'impédance. Ce processus se développe plus rapidement en viande de porc qu'en viande de boeuf. De la viande avec une valeur-Z élevée présente des valeurs-Z au-dessous de 1,10 après congélation suivi de décongélation. La détermination de la valeur-Z peut être une indication de la maturation de la viande.

Электрическая проводимость; критерий качества мяса?

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При помощи измерения в мясе электрической проводимости в пезуме двух частот (5 кгц и 100 кгц) можно подсчитать пропорцию импеданса (значение Z). Как у свинины, так и у говядины это значение вскоре после убоя животных является высоким (> 1,10). Затем значение падает ниже 1,10. Падение имеет связь с длиной отрезка времени между убоем животного и моментом измерения импеданции. Этот процесс происходит в свинине быстрее, чем в говядине. Мясо, значение Z которого является высоким, дает после замораживания и последующего оттаяния значения Z , находящиеся ниже чем 1,10. Определение значения Z может являться указателем состояния мягкости мяса.

Electrical conductivity; a meat quality criterion?

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Introduction

In a preliminary report (Van der Wal et al., 1977) we mentioned that impedance measurements on muscles at different frequencies may produce patterns that differ considerably from each other. A suggestion that this was a result of the meat's moisture content could not be confirmed, because the electrical conductivity patterns of PSE- (= pale, soft, exudative), normal and DFD- (= dark, firm, dry) pork are identical. Other experiments on electrical conductivity of meat have been made by Salé (1969, 1972) and Charpentier et al. (1972). Their aim was to discriminate between fresh, matured and frozen-thawed meat by comparison of two-frequency impedance measurements. The authors expressed their conductivity measurements in terms of a ratio, and named it Z-value. Their Z-value represents the impedance of a meat sample measured at 1 kHz divided by the impedance of the same sample at 100 kHz. Charpentier et al. (1972) found rather high Z-values in fresh beef, but which decreased during maturation and were very low in frozen-thawed beef. Our results (Van der Wal et al., 1977) are similar in general, but the Z-values found in matured and frozen-thawed meat are nearly equal. Remarkably, however, the shape of the curve of the impedance values at different frequencies changes from an "S-type" in fresh beef to a curve with a hyperbolic shape in frozen-thawed beef. To get an explanation for this phenomenon, meat samples have been studied at different times post mortem and also after freezing and thawing.

Material and Methods

Samples of three different bovine muscles have been studied at varying times post mortem. These beef samples have been collected from the longissimus dorsi, the pectoralis profundus and the triceps brachii muscles of 79 young bulls. The samples were measured for their impedance at different frequencies 2 to 6 days post slaughter, dependently from the time of sampling. The quotient of the electrical conductivity, as a measure of impedance, at 5 kHz and 100 kHz we call Z-value. Similar experiments were conducted with porcine longissimus dorsi muscles. In pork, however, we began our measurements a few hours post mortem. In a few cases, if a high Z-value was recorded, half of the meat sample (beef or pork) was frozen, while the other half was stored at 4°C. During storage the sample was wrapped in a plastic bag to prevent desiccation. The frozen sample was thawed the next day and measured just as a cold-stored sample. The measurements on the latter sample were continued every day till the Z-value had reached a value below 1.10. All measurements were taken at a meat temperature of 21°C. The electrodes were inserted into the sample's surface perpendicular to the direction of the fibres. An important factor is that the sample not be to dry.

The equipment used for the electrical conductivity measurements consisted of a measuring electrode containing two 7 mm stainless steel needles (Ø 2 mm) fitted at a 30 mm distance from each other in a glass needle holder. The electrodes, in serial with a 82.5 kΩ resistor, were connected to an oscillator (Solartron; type CO 546) by a coaxial cable and a vacuum tube voltmeter (Hewlett Packard; Model 400 H). The latter instrument gave the electrical conductivity readings. The whole system was calibrated, by measuring the tension over a 100 Ω resistor connected between the electrodes. Calibration of the oscillator tension was such (about 8.25 V) that the voltmeter gave 10 mV at a frequency of 1000 Hz. For every frequency the oscillator tension was adjusted to the value mentioned above. For each Z-value calculated, the tension measured, was plotted against the various frequencies (50 Hz to 100 kHz) used.

Results

Measurements on beef

Z-values were determined on meat samples from 79 young bulls. Because the animals were slaughtered at different days and the lapse of time between slaughter and sampling was not equal, we divided our results into several groups. Each group represented the Z-values of the samples which had been measured with the same time lapse. Five time groups were made for each of the three muscles (i.e. M. longissimus dorsi, M. triceps brachii and M. pectoralis profundus) as indicated in table I.

table I
Z-values measured in three different bovine muscles at different times post slaughter.

days post slaughter	M. long. dorsi			M. pect. prof.			M. triceps brachii		
	n	$\bar{x}$	Sx	n	$\bar{x}$	Sx	n	$\bar{x}$	Sx
2	19	1.43	0.53	19	1.42	0.45	19	1.10	0.12
3	7	1.37	0.38	7	1.37	0.21	7	1.04	0.01
4	13	1.16	0.21	13	1.18	0.18	13	1.08	0.14
5	33	1.08	0.06	33	1.14	0.12	32	1.06	0.06
6	7	1.10	0.09	7	1.22	0.21	7	1.06	0.04

It became clear from these results that the Z-values are still rather high two days after slaughter in longissimus dorsi and pectoralis profundus muscles, but they decrease with time post slaughter.

In another experiment we studied the relation between the lapse of time and the decreasing Z-value. In this experiment the same beef samples were measured for several days, and followed by a freezing and thawing procedure (table II).

table II
Z-values measured in the M. longissimus dorsi at different days and after freezing and thawing.

days post slaughter	Z-value
3	1.61
6	1.16
9	1.09
after freezing and thawing (Z-value: 1.61)	1.02

The results of this experiment, as indicated in the table, were similar to comparable experiments. The initial Z-values were always higher than that of the following measurements. In all cases, however, Z-values determined in meat after freezing and thawing were below 1.10. This strengthened the opinion that there is a relation between Z-value and the lapse of time between killing the animal and determining the electrical conductivity.

Measurements on pork
As maturation of beef is rather slow in comparison with pork, we started a series of experiments on porcine longissimus dorsi muscles. Therefore 25 longissimus dorsi samples were collected about 24 to 30 hours after slaughter. The Z-values, measured in these pork samples, are given in table III.

table III
Z-values of porcine longissimus dorsi muscles, determined 24 to 30 hours post slaughter and after freeze-thaw.

fresh			frozen-thawed		
n	$\bar{x}$	Sx	n	$\bar{x}$	Sx
20	1.37	0.65	-	-	-
5	1.11	0.02	5	1.02	0.01

Table III shows that average Z-values of fresh pork are rather low, when measured 24 to 30 hours post slaughter (i.e. 14 of 20 pork samples had Z-values below 1.10, while only 4 samples were higher). The group with the low Z-values included both normal as well as PSE pork. Samples that were determined after a freezing and thawing procedure produced values significantly below 1.10. The differences between the average Z-values of fresh and frozen-thawed pork, however, are minimal. The question is then, are Z-values in pork generally low, or have they already reached a low value prior to the time of the measurements? To study this question M. longissimus dorsi samples from pigs were taken immediately after slaughter, and measurements began immediately. The results of one of these experiments are shown in fig. 1.

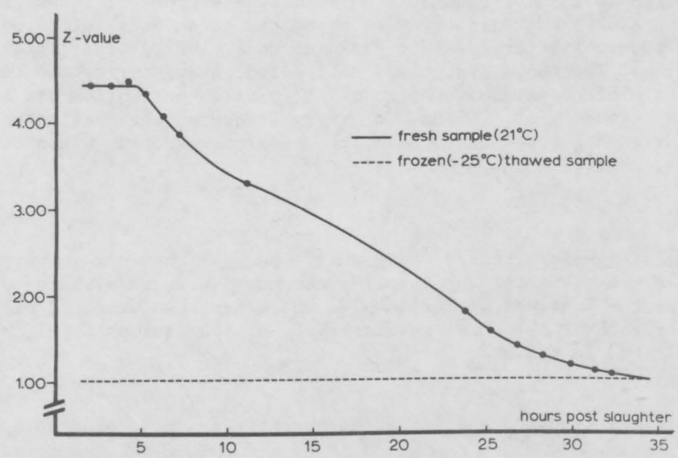

fig. 1. Z-values from a porcine M. longissimus dorsi sample measured during a period of 48 hours post slaughter, and after freezing and thawing.

The initial Z-values are very high and remain at that level about 4 to 5 hours. Thereafter a decrease starts, which proceeds to 30 to 33 hours post slaughter. At this moment the Z-values have gone below 1.10. The result is that the "S-shaped" curve, we found initially, has become a hyperbolic curve. The same result was found in other comparable experiments.

Discussion
It was found, as indicated in a previous report (Van der Wal et al., 1977), that the electrical conductivity was different among individual bovine muscles. This could be shown by drawing the electrical conductivity curves at frequencies in the range from 50 Hz to 100 kHz. Electrical conductivity (mV) was used as a measure for impedance. Two types of curves were found. These were an "S-shaped" curve and a hyperbolic curve. Similar to the research of Charpentier et al. (1972) we expressed our conductivity measurements in a Z-value using, however, the quotient of the conductivities at 5 kHz and 100 kHz. These two frequencies were more satisfactory than the 1 kHz and 100 kHz used by Charpentier et al. (1972).
It was found that the "S-shaped" curve corresponded with Z-values higher than 1.10, while the hyperbolic curves always were characterized by Z-values less than 1.10. Therefore it is reliable to use only Z-values rather than

taking measurements over the whole frequency range. A high Z-value is the result of a greater impedance of the tissue at lower frequencies (5 kHz) than at 100 kHz. During maturation and also after freezing and thawing the electrical conductivity of the tissue increases, especially at lower frequencies, while at higher frequencies (100 kHz) the tissue's electrical characteristics do not change very much, as also reported by Salé (1972). Maturation as well as freezing procedures result in low Z-values, which approach 1.00. It can be stated that both, maturation and freezing, of beef and pork decrease Z-values. Salé (1972) and Charpentier et al. (1972), who described comparable developments, related their findings to changes of the cellular membranes. Our study agrees with them, especially when we take into consideration the very rapid decreases that can be provoked by a freezing procedure. With such a method we can artificially accelerate the whole maturation process by causing severe damage to the membranes. A process that develops more moderately in maturation.
The determination of Z-values shows that important differences exist between beef and pork. Maturation in pork is more rapid than in beef according to the Z-value measurements. Pork maturation has finished within about 33 hours post slaughter, while in beef this may take several days (tables I and II). This corresponds to the fact that beef is sold in retail after a longer period post slaughter than pork. A practice that is consistent with the meat's maturation process.

Conclusions

- Measuring the electrical conductivity at two frequencies (5 kHz and 100 kHz) may give information about the meat's maturity.
- Maturation can be expressed by the Z-value, which is the quotient of the electrical conductivity at two frequencies (5 kHz and 100 kHz).
- Maturation in pork is more rapid than in beef.

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