51st International Congress of Meat Science and Technology
August 7-12, 2005 – Baltimore, Maryland USA

BURGER TEXTURE IN VIEW OF PHYSICAL CHARACTERISTICS OF MEAT DOUGH AND PATTY FORMING PROCESS

A. Jurgens[1], T.J. Verkleij[1] J.D. de Mooij[2],

[1]*TNO Quality of Life, P.O. Box 360, 3700 AJ Zeist, the Netherlands,*
[2]*Stork Titan B.V., P.O. Box 233, 5830 AE Boxmeer, the Netherlands.*

Key Words: patty forming, burgers, rheology; thermal analysis; texture; meat dough

Introduction

Control of product characteristics and quality, and efficient adaptation to changes in desired quality through dedicated processing are important issues for the industry. Major aspects of consumer appreciation comprise visual appearance like colour and shape, textural aspects like bite and chewing properties, taste and smell. These characteristics depend on composition as well as on processing conditions. An often neglected aspect in process optimization is the interrelation between raw material properties and processing with regard to quality. An extensive overview was given by Mikkelsen (1993). However, most studies in this context have been published on the relation of texture, cooking loss and microbial safety with the heating process, e.g. Erdogu et.al. (2005) and Zorrilla et.al. (2000) The relation between patty forming process and product characteristics didn’t receive much attention.

The present work relates, in more detail, to the relation between the physico-chemical properties of the meat dough, the thermal conditions during the patty forming process and rest after forming on final physical texture of poultry meat burgers after heating. The aim is to understand the different factors that dominate the quality aspects mentioned.

Objectives

Make manifest the interacting effects of process conditions during forming and meat characteristics on the final structure of burgers.

Methodology

Experimental work was based on meat doughs using simple basic formulations (table 1).

Meat preparation, storage and patty preparation

Chicken breast fillet and thigh meat were ground over 13 mm plates, chicken skin was ground over 2 mm plates (4°C). Salt and water (0°C) were added, while mixing in a cutter for 5 minutes. Next the skin and starch were added following another 10 minutes of mixing, while the temperature was kept at 4°C. The meat was divided and stored frozen at temperatures between 0 and -8°C for 1 day till 4 days. Within each test series storage time and temperature were kept constant. A number of additional tests were performed with varying cutter time, from 1 till 13 minutes to examine free protein release in relation to dough elasticity.

Patties were formed at temperatures of 0, -2.5, -6 and -8.5 °C by use of a hydraulic press and a mould of 100 mm in diameter. Patties were formed with different heights depending on the subsequent tests. Patties prepared for heating and end product testing were 12 mm high. Those prepared for rheological testing of the meat dough were 5 mm high, whereas those intended for texture analysis of the doughs had a height of 15 mm. Effective pressure on the dough during forming was 4 bar during 5 seconds.

Heating

Each patty was treated outside with soy oil and packed in aluminium foil. Heating took place in a Fessman hot air oven, set at 90°C and an RH of 100% during 30 minutes. Under these conditions a core temperature of about 70°C was reached.

Physical testing

Physical characteristics of the dough were determined by differential scanning calorimetry (DSC), dynamic rheological testing and texture analysis.

DSC was performed with a TA Instruments 2920 calorimeter by scanning from -40°C up to +20°C with a scanning rate of 2°C/min. Samples were homogenised under cryogenic conditions and about 15 mg was taken to determine the heat flow during heating.

Dynamic rheological testing on meat dough was performed by using a Carri-Med CSL^2-500 type stress controlled rheometer. This rheometer was equipped with serrated parallel flat plate geometry with a diameter of 40 mm and an ETM type temperature control unit using liquid nitrogen. The gap setting was 5 mm and an oscillatory shear was performed with a fixed amplitude of deformation of 10^{-3} (-) and a frequency of 1 Hz. The amplitude of deformation was selected within the linear region which extends up till about 2.10^{-2}. A temperature sweep was recorded at a rate of 1°C/min., during which the storage-(G’) and loss-(G”) moduli were recorded. Samples were applied at a temperature of -10°C.

Free protein in meat dough was determined with a Technicon Infralyser 400 near infrared spectrometer using the calibration method analogous to Oh and Groβklaus (1994) .

Heated burgers were tested using a Stable Micro Systems type TA-XT21 texture analyser with a flat disc steel probe (diameter 100 mm). A texture profile analysis (TPA) test was performed (Szczesniak (1973)), which comprises two subsequent compressions. Probe speed was 1 mm/sec and a maximum deformation of 40%. As relevant parameters we selected hardness and cohesiveness. At each process condition, TPA tests on heated samples were performed on 15 products in a first test series determining the effect of temperature of forming, and 8 products in the test series determining the effect of dough rest on texture.

Results & Discussion

Meat dough characteristics

Figure 1 shows the release of free protein in doughs, containing 15% fat, prepared with different cutter times as determined by NIR and the resulting elastic modulus (G’) in relation to the free protein measured.

The results clearly show the effect of cutter time with protein release and its effect on the elasticity of the dough. Dough elasticity was found to vary by 40% depending on the cutter time as a result of protein release. The main effect found on final product quality with increasing free protein concentration was an increasing shrinkage. Shrinkage is expressed as the difference in diameter of the heated hamburger (d_{burger}) *with* the diameter of the patty (d_{patty}) direct after forming: $\Delta d=(d_{burger}-d_{patty})/d_{patty}*100$ (%). We found the following relationship between shrinkage and free protein concentration, as found by NIR : $\Delta d=-0.28*C_{protein}$ (%). In the following tests the cutter time kept constant at 5 minutes, resulting in a free protein concentration of 11.2±2.0%.

The mechanical behaviour of the meat dough, as a function of temperature is presented in figure 2. This figure shows the storage (elastic) modulus and tan(δ), the ratio of the loss (viscous) and storage modulus, of the dough during heating in the rheometer. The storage modulus is a measure of the elastic rigidity of the dough at very small deformation. The results of the dough stored at -2°C were not significantly different, indicating that storage temperature over the short storage time applied, did not affect the structure. The rheological differences (G’and tan(δ)) between the fat concentrations were small and not significant compared to changes in these parameters as a function of temperature during defrost. Within the range of -10 till about -7°C the structures were too rigid to determine the moduli.

From -6°C till -4 °C the storage modulus weakly decreases, while the loss angle (tan(δ) =G”/G’) slowly increases from 0.1 up to 0.2. The loss angle is a measure of the ratio of elastic and viscous behaviour of the sample, the lower the value, the higher the elastic behaviour. Values below 1 indicate that elastic behaviour dominates over viscous loss. Below -4°C the dough behaves as an elastic solid with highly dominating elastic behaviour. Above -4°C the elastic modulus strongly decreases until a temperature of about 2°C is reached, Between -4°C and -3°C tan(δ) strongly increases up to values of about 0.35. This sudden increase in tan(δ) indicates a strong change in structural behaviour with more viscous loss. Above 2°C the elastic modulus decreases very slowly.

Figure 3 presents the heat flow during heating of a meat dough sample stored containing 5% fat in the temperature range from -15 till +10°C. Included in this figure is the elasticity (G’) of the same meat dough.

Dominating in the thermogram is the melting of ice. Frequently only the peak temperature of the melting is recorded, but the results show that the complete melting profile is relevant to the elasticity of the dough (see fig 3) and therefore for optimal processing. Note that melting already starts at very low temperatures and the absolute onset of melting is hard to detect since the deviation of the horizontal baseline is difficult to identify. This melting behaviour can be understood on the basis of the freezing process and the concept of freeze concentration. Integration of the melting peak results in the total heat of melting. Combining with the literature value for the heat of melting of ice, 334 J/g, provides the possibility to calculate the amount of frozen water in the sample. Comparison with the total water content in each sample delivers the amount of bound or unfreezable water. In two types of meat doughs, one containing 5 % and the other 15% fat the concentration of unfreezable water found in this way was respectively 13.2 and 13.4 %, while the amount of free (ice forming) water was respectively 54.8 and 59.6%. Freezing characteristics, as presented here, dominate product quality and are therefore considered relevant to other type of formulations.

Heated product texture

Hardness- and cohesiveness values obtained from the TPA tests of the heated burgers (15% fat) formed at different temperatures are presented in figure 4. Error bars indicate the (95%) standard error obtained from 15 repeats.

From the results it is obvious that the internal product structure is more weakened by forming at lower temperatures. At lower temperatures products contain more ice so deformation during forming therefore requires much more stress (energy) compared to forming at higher temperatures. Higher stress will cause more deterioration of internal bonds which apparently do not recover within the timeframe of dough rest between forming and heating.

Dough rest

In order to study the effect of dough rest in more detail, the rheology of patties formed at -8°C and at 0°C was compared within 15 minutes after the forming process. Figure 5 shows an example of the change in tan(δ), i.e. ratio between viscous loss and elastic storage modulus, with time when measured at 12°C. A higher tan(δ) indicates more viscous like behaviour, while a more elastic like behaviour is indicated by lower tan(δ) values.

While the patty formed at 0°C hardly showed any change in the value of tan(δ) with time, the patty formed at -8°C decreased strongly within the first 20 minutes of measurement and more slowly thereafter until it became equal in value to the dough formed at 0°C. This suggests a complete recovery of the structure of the dough formed at -8°C, at least comparable to that of the dough formed at 0°C after about 1 to 2 hours.

At several dough rest times after forming, patties were heated to study the effect of rest time on texture. Hardness and cohesiveness, determined with the TPA test, of heated products after different dough rest times is presented in figure 6. Error bars indicate the (95%) standard error of 8 repeats.

We note that the absolute values of hardness and cohesiveness differ from values obtained in an earlier experiment; this could be due to batch to batch variations. Nevertheless we observed lower hardness when patties were formed at lower temperatures, except after about 1000 minutes (about 17 hrs!) dough rest. Cohesiveness was also lower for the lower temperature at forming and showed to be independent of dough rest time. These results show that an irreversible structure breakdown occurs during forming at a low temperature of -8°C, which was unexpected when compared to the recovery of the mechanical behavior, tan(δ) presented in figure 4. This is not yet fully understood.

Conclusions

The mechanical behaviour of the poultry meat doughs processed within the temperature range of -10°C till 5°C, and the texture of heated products was dominated by the melting profile. Three principal temperature ranges could be identified:

1. T<-4°C, in which the dough behaves as a rigid mass which is mechanically difficult to deform.
2. -4°C<T<0°C, in which the consistency of the dough is subject to a rapid change, due to a strong change in melting. This is a critical range since fluctuations in temperature will lead to strong variations in final product texture.
3. T>0°C above which the mechanical dough characteristics vary not much.

Thermal analysis of the melting profile of the doughs tested showed to be in good relation to the mechanical dough properties and the forming process at the different temperature ranges. Variations in formulation will change the mechanical and thermal characteristics. We have shown that a variation from 5 to15% fat lowered the consistency slightly but did not change the main behaviour.

Varying temperature during forming showed to have a significant effect on the final product texture after heating. This effect was most apparent in changes in cohesion in the product. It was shown that more breakdown of dough structure occurred at lower temperatures during forming. During dough rest the mechanical behaviour of the patty, formed at relatively low temperatures, recovered. However, cohesiveness of heated burgers after forming at relatively low temperatures was always significantly lower than products being formed at relatively higher temperatures.

References

Erdogu, F., Zorilla, S.E., Singh, R.P. (2005), Effects of different objective functions on optimal decision variables: a study using modified complex method to optimize hamburger cooking., Food Sci. and Techn., 38, 111–118

Mikkelsen, V.L., (1993), Hamburger patty technology: a literature review, Publ., Meat Ind.Res.Inst.of New Zealand, 932

Oh, E.K., Groβklaus, D. (1994) Measurement of components in meat patties by near infrared reflectance spectroscopy, Meat Sci., 41, 157–162

Sczczesniak, A.S. (1973), Instrumental methods for texture measurements, in Texture Measurements of Foods, Kramer, A and Szczesniak, A.S eds., D. Reidel publ. company, Dordrecht, Boston, pp 71–108.

Zorrilla, S.E., Rodevo, C.O., Singh, R.P. (2000), A new approach to correlate textural and cooking parameters with operating conditions during double-sided cooking of meat patties, J. Texture Studies, 31, 499–523

Tables and Figures

Table 1. Meat compositions

	"5% fat" (%)	"15% fat" (%)
Breast fillet	72.5	52.5
Thigh meat	17.8	19.8
Skin	0.0	20.0
Water	7.0	5.0
Starch	2.0	2.0
Salt	0.7	0.7

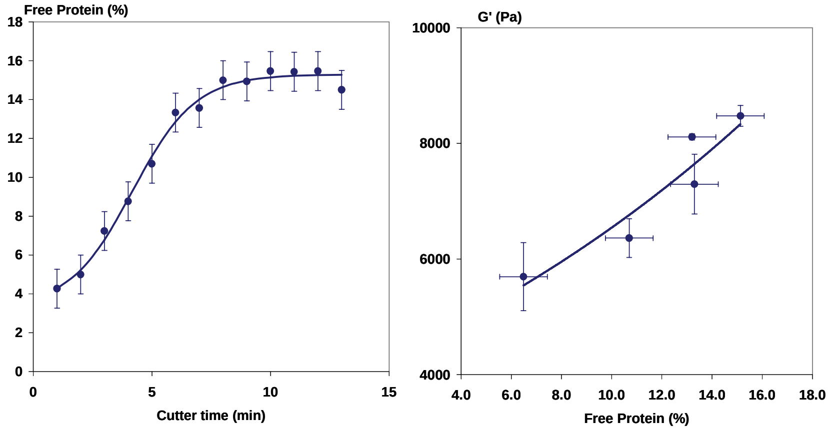

Figure 1. Free protein (NIR) as a function of cutter time (left) and resulting meat dough elasticity at 20°C (right).

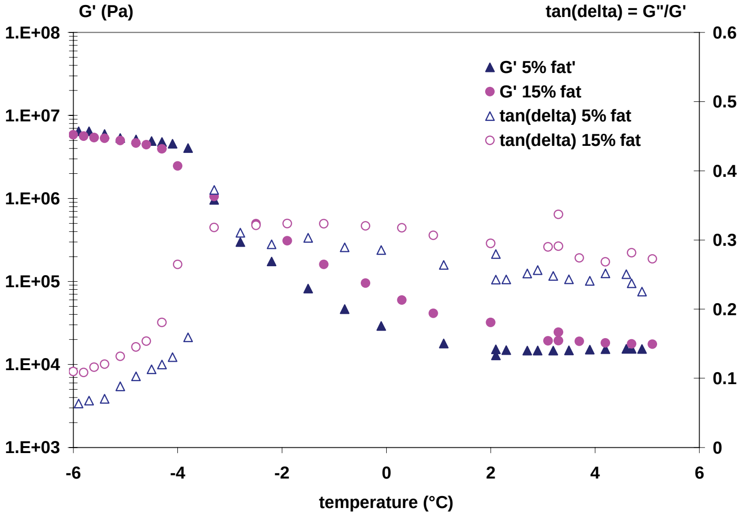

Figure 2. Storage moduli and loss angle of meat doughs, stored at -6°C.

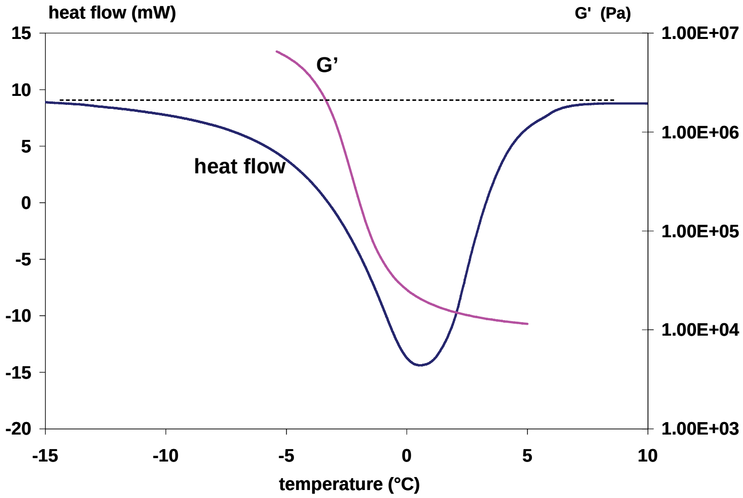

Figure 3. Heat flow determined by DSC during melting of a meat dough sample with 5% fat and the elasticity of the sample dough determined by dynamic rheology

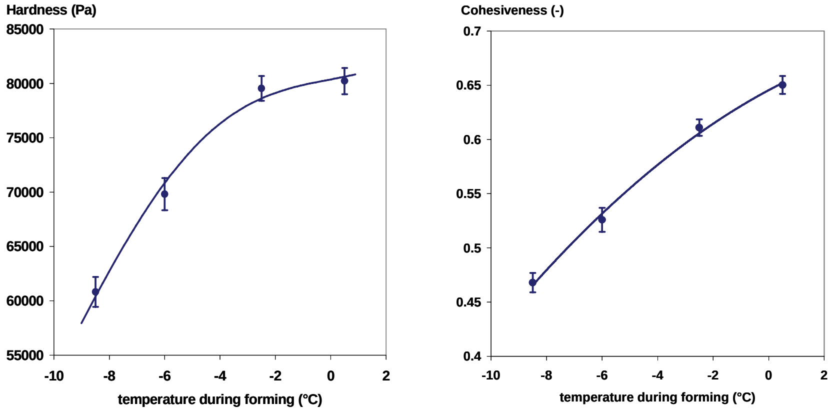

Figure 4. Hardness and cohesiveness of heated burgers.

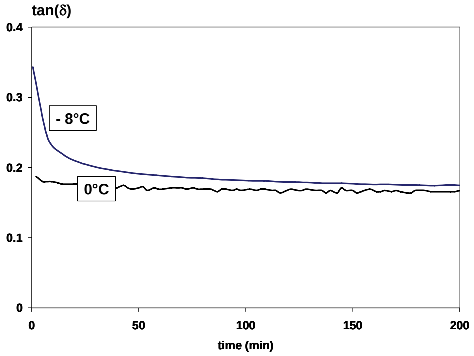

Figure 5. Tan(δ) vs. dough rest time of doughs formed at 0 and -8°C

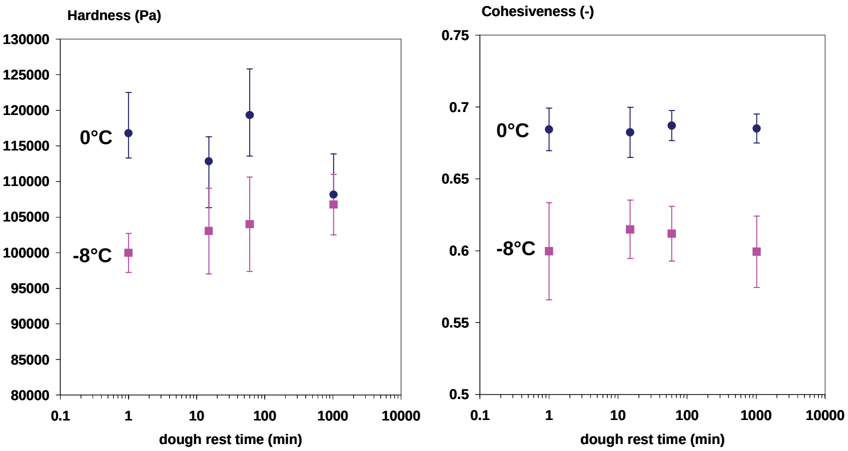

Figure 6. Hardness and Cohesiveness of heated patties.