Application of pork fat diacylglycerols in meat emulsions

Rikke Miklos\textsuperscript{a}, Xuebing Xu\textsuperscript{b}, René Lametsch\textsuperscript{a,⁎}

\textsuperscript{a} Department of Food Science, University of Copenhagen, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark
\textsuperscript{b} Department of Molecular Biology, University of Aarhus, Gustav Wied's Vej 10, DK-8000 Aarhus C, Denmark

1. Introduction

The quality of fat is an essential aspect in the production of meat products. The specific role of fat differs between types of products but affects the rheological and structural properties of the product besides contributing to succulence, flavour and texture. In the production of meat emulsions, the physical properties of the fat fraction are crucial in the formation of a stable emulsion as fat stabilises the solubilized protein gel and helps to prevent shrinkage of the protein during cooking by acting as a filler (Feiner, 2009; Lurueña-Martinez, Vivar-Quintana, & Revilla, 2004). The technological quality of fat is determined by the fatty acid composition, the position of the fatty acids in the glycerol backbone, the melting point and the crystallisation behaviour (Davenel, Riaublanc, Marchal, & Gandemer, 1999). In pork fat these properties depend on breed, feed, age and slaughter weight of the individual pigs (Hernandez, Navarro, & Toldra, 1998; Hugo & Roodt, 2007; Wood et al., 2008). Hence, variation in the fat quality is a major issue, which manufacturers of meat products have to face (Davenel et al., 1999) and problems associated with poor fat quality are a serious challenge (Hugo & Roodt, 2007).

By enzymatic modification the physical and chemical properties of fats and lipids can be manipulated in several ways, e.g. interesterification with other oils and fats and by formation of partial acylglycerols (Renne, Yang, Mu, Jacobsen, & Xu, 2005; Vu et al., 2007; Weber & Mulherjee, 2004; Xu, 2000). Thereby enzymatic modification of pork fat opens new ways to affect the technological quality.

In general, partial acylglycerols in the form of diacylglycerols (DAGs) have higher melting points compared with their corresponding triacylglycerols (TAGs), which serve as a new possibility to overcome problems with texture. Since DAGs have a hydrophilic polar group in the molecular structure and exhibit surface activity, DAGs have the ability to form emulsions and retain water (Nakajima, 2004). As the water holding capacity in meat products normally is increased by addition of salt and phosphates, a stronger water retention caused by partial acylglycerols can be speculated to reduce the need for salt and addition of phosphates can maybe be avoided in some meat products. In addition DAGs have been reported to result in a lower fat accumulation in the human body (Flickinger & Matsuo, 2003; Maki et al., 2002; Meng, Zou, Shi, Duan, & Mao, 2004; Murase, Aoki, Wakisaka, Hase, & Tokimitsu, 2002). Cooking oil based on DAGs is already on the markets in Japan and USA, where DAGs have been evaluated as “generally recognized as safe (GRAS)” by FDA (Morita & Soni, 2009).

In this study the application of pork diacylglycerols (DAGs) produced from lard by lipase-catalysed glycerolysis has been investigated in meat emulsions. The aim of this work was to investigate the effect of substitution of TAGs with DAGs in meat emulsions for evaluation of the future perspectives of use of DAGs in meat products.

2. Materials and methods

2.1. Preparation of meat

Pork \textit{Semimembranosus} muscles (pH 5.65–5.77) were purchased from a local meat market. All visible fat and connective tissue were removed before cutting into smaller pieces. The pieces were mixed...
and minced twice in a mincer with a 3 mm plate. The minced meat was mixed thoroughly and divided into portions of 480 g, vacuum packed and stored at −18 °C. When needed the samples were thawed for 15 h at 4 °C.

2.2. Preparation of DAG

Rendered lard was supplied by a local slaughterhouse and used in the enzymatic production of DAGs. Lard and glycerol in 1:1 mole ratio were mixed in a batch reactor at 90 °C. Vacuum at 20–30 mbar was applied for 30 min to dry the mixture. The temperature was then readjusted to 70 °C and 10 wt.% Novozym 435 was added at 300 rpm stirring. The reaction was conducted for 8 h. The mixture was filtered to remove the enzyme. The mixture was stored at −20 °C before purification. The DAGs were purified by short path distillation conducted by Danisco (Aarhus, Denmark) resulting in a product containing: DAG > 94%, glycerol < 1%, and FFA < 1.5%.

2.3. Preparation of fat mixtures

Lard and DAGs derived from the same batch of lard were used in the production of emulsions to minimize differences in fatty acid composition. Hence, it can be assumed that changes in properties can be ascribed to changes in the acylglycerol structure rather than differences in fatty acid composition. For the preparation of fat mixtures lard and DAG were melted in a 70 °C water bath until no visible crystals were present. Mixtures containing 10% and 50% DAGs were prepared by weight, packed in portions of 250 g and stored at −18 °C. The samples were thawed at 4 °C for 15 h before use.

2.4. Preparation of emulsions

The emulsions (aimed to contain: 10% protein, 25% fat, 60% moisture, and 0.5% starch) were prepared in batches of 1 kg in a food processor (CombiMax 600, Braun, Germany). Thawed meat (480 g), potato starch (5 g), curing salt (NaCl with 0.6% of nitrite) (17 g) and crushed ice (248 g) were comminuted at highest speed for 2 min. The temperature at this point was 1 °C in all batters. After addition of 250 g of hand chopped cubes of lard or fat mixtures the batter was comminuted for 2 min. The temperature was measured (approx. 12 °C) and comminuting was continued for 1 min. End temperature was 14 °C. All emulsions were prepared twice at different days.

Four cans were filled with 180 g (+/−5 g) of emulsion, closed and heated for 35 min. in a boiling water bath (core temperature of about 90 °C). After the heat treatment the cans were cooled in running tap water for 5 min and stored at 5 °C for 24 h. The rest of the raw emulsion was used for determination of emulsion stability.

2.5. Jelly and fat separations

The jelly and fat separations were measured as described by Bloukas and Honikel (1992) and Lurueña-Martínez et al. (2004). After cold storage for 24 h two cans from each batch were reheated in a water bath at 45 °C for 1 h. The cans were opened and the fluid from each can was collected in a volumetric cylinder. After clear separations in jelly and fat and the temperature of the fluids had reached 22 °C, the amounts were determined in milliliters and calculated as percentage of the original weight of the batter (specific weight of 1.0 g/mL were used for both jelly and fat). Mean values of the two cans were used for each emulsion.

2.6. Emulsion stability

The procedure of Hughes, Cofrades, and Troy (1997) was followed. Approximately 25 g (exact weight noted) of the raw emulsion was weighed into a 50 mL centrifuge tube (four replicates) and centrifuged for 1 min at 2700 g. The centrifuge tubes were then heated in a 70 °C water bath for 30 min and centrifuged for 3 min at 2700 g. The supernatants were poured into pre-weighed aluminum containers and pellets and centrifuge tubes were re-weighed. The supernatants were dried overnight at 100 °C and weighed. The volumes of total expressible fluid (TEF) and the percentage of fat (%Fat) were calculated as follows:

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\text{TEF} = (\text{weight of centrifuge tube and sample}) - (\text{weight of centrifuge tube and pellet})
\]

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\%\text{TEF} = \frac{\text{TEF}}{\text{original sample weight}} \times 100
\]

\[
\%\text{Fat} = \frac{\text{Weight of dried supernatant}}{\text{TEF}} \times 100
\]

2.7. Texture

The texture of the 24 h cold stored canned emulsions was determined using an Instron Universal Material Testing Machine (Instron 5564, England). From each can six cylindrical cores (diameter: 18 mm; height: 20 mm) were prepared. The samples were placed on a platform and each one compressed once to 10% of its original height at a cross head speed of 50 mm/s using a 25 kg load cell. Force–time curves were recorded. From each emulsion two cans were used to make twelve replicates. Young’s modulus (elasticity) and maximum hardness were calculated by plotting values of stress against strain. Young’s modulus was calculated as the slope of the linear part of the curve before the first peak. Maximum hardness was determined as the amount of stress corresponding to the height of the first peak.

2.8. Statistical analysis

One-way analysis of variance was carried out with the Statistical Analysis System version 9.1 (SAS Institute Inc., Cary, NC, USA). The GLM procedure was applied when calculating least squares means (LSM) and standard errors (SE) and the option PDIFL was used for calculating significant differences between LSM. Differences with P-values < 0.05 were considered to be significant.

3. Results and discussion

3.1. Water and fat retention

Measurements of jelly and fat separations and emulsion stability of the meat emulsions give information about the ability to retain moisture and fat upon further processing (Lurueña-Martínez et al., 2004). In this experiment the fat and moisture retentions are generally poor compared with other studies of emulsion products (Aktas & Genccelep, 2006; Lin & Huang, 2003; Lurueña-Martínez et al., 2004). The relatively high release was an intended effect, which was taken into account when the recipe was formulated with a relatively high fat/protein ratio and a very low level of starch in order to enhance the effect of the DAGs and highlight possible improvements.

The presence of DAGs in the meat emulsions did increase the emulsion stability. The total expressible fluid (%TEF) decreased significantly (P = 0.044) when the amount of DAGs increased (Fig. 1). The %TEF was 28.2% when pure lard was used and when the lard was completely substituted by DAG the %TEF was decreased to 11.8%. The percentage of fat separated in the expressible fluid (%Fat) decreased significantly (P = 0.044) when lard was completely substituted by DAGs. When lard was only partly substituted by DAGs no significant effect was observed on the fat percentage in the expressible fluid. However, when the cooked emulsions were allowed to set for 24 h before re-heating the fat binding was improved significantly (P<0.0001) as reflected in the measurements of jelly and fat separations (Fig. 2).
Substitution with only 10% DAG resulted in a significant decrease in fat separation from 10.9% in the control emulsions to 7.8% in the emulsions prepared with 10% DAG. For the emulsions prepared with 50% and 100% DAG practically no fat separation was observed. In general, the jelly separation in the reheated emulsions was not affected ($P=0.094$). However, when lard was completely substituted with DAGs the jelly separation decreased significantly from 15.2% to 9.3%.

TEF consists of jelly and fat that are not held by the protein network formed during heat treatment. It has been suggested that the fat loss in emulsion sausages mainly is correlated to the properties of the fat whereas the water loss reflects the properties of the protein matrix (Andersson, Andersson, & Tornberg, 2000). Application of DAGs changes the properties of the fat fraction, which explains why the fat separation is more affected than the jelly separation. However, in contrast to lard, DAGs are capable of retaining water due to the ability to form W/O emulsions and thereby affect the water holding (Nakajima, 2004). The results of the emulsion stability indicate that in meat emulsions DAGs do not only have an effect on the fat binding but also the ability to retain water.

The discrepancies in the results, due to how the water fraction and fat fraction are affected depending on the method, can be explained by the fact that emulsion stability is measured on freshly prepared batter at a cooking temperature of 70 °C, whereas jelly and fat separations are determined on cooked emulsions stored 24 h and reheated at low temperature of 45 °C. The cooking temperature influences on the physical state of the fat as a temperature of 70 °C will cause a complete melting of the fat, whereas heating at 45 °C is just above the melting point of lard and may cause differences in the physical state between the samples due to differences in melting points. In addition the stability of the protein gel structure will be affected differently according to the extent of the heat treatment. However, the overall conclusion is that both water and fat losses decrease with increasing amount of applied DAGs, but the observed effect is affected by the end-point temperature of the re-heating.

### 3.2. Texture

The texture measurements showed that the use of DAGs in meat emulsions had a significant effect on the texture of the emulsion (Figs. 3 and 4). The emulsions containing DAGs were more firm and solid reflected in an increase in Young’s modulus ($P=0.0007$) and the maximum hardness ($P=0.010$) corresponding to the increase in
the content of DAG. A significant effect was observed even with 10% of DAG. This effect can be speculated to be explained by a stronger interaction between the fat fraction and the protein gel due to the polar hydrophilic group in the DAGs. In addition the fact that DAGs have higher melting points than TAGs is likely to influence the hardness of the product.

4. Conclusion

The results show that the properties of meat emulsions can be changed by substitution of pork fat with pork DAGs resulting in more stable emulsions. The results may serve as inspiration for future perspectives of application of DAGs in meat products and enzymatic modification of the functionality of lard.

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References


