MONITORING THE LIPID STRUCTURE OF FRANKFURTERS: TOWARD A FOOD MODEL TO BETTER UNDERSTAND THE PERCEPTION OF FAT.

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Abstract – This present work aims to develop Frankfurters to study the modalities of fat perception in mouth. Different Frankfurter-types were performed to study the effect of the process (*i.e.* the initial temperature of ingredients 0°C *versus* 5°C) and the formulation (*i.e.* the addition fibers or starch) on the lipid structure. Each Frankfurter emulsion was characterized by measurements of lipid oxidation and texture profile. The size of fat droplets was determined by histochemical analyze with the red oil staining. Results showed that the process at low temperature reduced the lipid oxidation and the size of fat droplets. Frankfurters present a texture profile firmer but less deformable than those manufactured with ingredients at 5°C. The formulation lever induces an increase of the size of fat droplets and shear force. Interestingly addition of fibers or starch did not affect the lipid oxidation neither the firmness of Frankfurters.

Key Words – Frankfurters, lipid structure, meat emulsion, microscopy, rheology.

I. INTRODUCTION

In Western diets, the daily amount of fat is 10% upper than the level recommended by the international nutrition agencies [1]. This high fat diet is generally associated with health problems such as diabetes and obesity. Studies in human have demonstrated a spontaneous preference for fatty foods [2]. The origin of this sensory preference is not yet well understood. Food models are relevant tools to study relationships between food properties and sensory response of subjects during consumption. For example, the variation of the emulsion structure in foodstuff induces changes in sensory perception [3]. In this context, the development of food model, *i.e* emulsion type, would allow to understand the effect of variables, such as fat content, droplet size and thickening agents on sensory perception of consumers. To establish a link between the structure of food model and the perception of fat in mouth, the lipid structure in the food model requires to be controlled. For this purpose, an emulsion sausage Frankfurter-type was chosen. This emulsion is composed of *i)* a continuous phase which include water, spices, lean meat and *ii)* a disperse phase with air bubbles and emulsified lipid. In general, Frankfurters may contain up to 30% fat but in our study, the fat level was reduced to 14% to fit nutritional recommendations. The finality is to design low-fat Frankfurters without altering their textural and organoleptic characteristics in order to preserve an overall sensory acceptability for consumers. For that, two levers were investigated: the first one is the process, which aims to use ingredients at low temperature for extending the cuttering duration and possibly the lipid dispersion [4, 5]; the second one, is the formulation which consists of adding vegetable fibers or starch to modify size and the distribution of fat droplets within the meat emulsion [6]. The target of this present work is to develop four different frankfurters by using the process and the formulation levers to modify the structure of the lipid phase.

II. MATERIALS AND METHODS

Emulsion manufacturing. Pork lean and fat, sodium nitrite, lactose, spices, freeze-dried pig plasma and psyllium fibers or tapioca starch were used as ingredients to manufacture emulsion. The fresh pork lean and backfat, coming from Bleu-Blanc-Coeur sector, were obtained from a local slaughterhouse. Four different meat batters were prepared. To study the effect of process, two meat batters were made, by modifying the temperature of raw ingredients (0°C *versus* 5°C, Table 1). To assess the formulation effect, two meat batters were formulated: one with psyllium fibers and one with tapioca starch (Table 1). All the ingredients were mixed until a final temperature of 12°C. The batters were stuffed by a piston stuffer into a 22-24 mm diameter sheep gut (DS-France S.A.S., Thiais, France). Frankfurters were heat processed in a steam room for 15 min at 50°C, and then 60 min at 60°C. They were then steamed in a water bath for 40 min at 67°C. The frankfurters were cooled, vacuum-packed and stored at 4°C ± 1°C until analysis.

Table 1 Formulation of Frankfurters (g/100g).

Samples	C 5°C	F 0°C	F/FP	F/TS
Ingredient temperature (°C)	5	0	0	0
Backfat	14	14	14	14
Meat	66	66	66	66
Plasma	3	3	3	3
Nitrite salt	2	2	2	2
Spices	0.3	0.3	0.3	0.3
Lactose	0.5	0.5	0.5	0.5
Ice	14	14	11	11
Fibers or Starch	0	0	3	3

C 5°C, control frankfurter; F 0°C, Frankfurters made with ingredients at 0°C; F/FP, Frankfurters with ingredients at 0°C + psyllium fibers; F/TS, Frankfurters with ingredients at 0°C + tapioca starch.

Lipid oxidation was measured by the ThioBarbituric Acid Reactive Substances (TBARS) method [7]. Replicates were performed for each meat batters.

Texture profile analysis was carried out on each Frankfurters with a textural device using a Warner-Bratzler cell (Instron France S.A.S., Guyancourt, France). Young modulus was determined on peeled circular sections of Frankfurters (height = 2 cm) which were crushed perpendicularly. Shear force was assessed on peeled, parallelepiped samples of sausage (height=1,5cm, length=2cm). Ten replicates were performed for each frankfurter.

Microstructure analysis. Size and repartition of the fat droplets were analyzed using light microscopy. For each meat batter, a sample of about 2 cm of sausage was frozen in cooled isopentane chilled with liquid nitrogen (-160 °C). Thin transverse serial sections (10 µm thick) were cut using a cryostat at -22 °C (Microm, HM 560), mounted on slides and air dried (20 °C). Each section was stained using Red Oil to reveal fat droplets. Observations were performed using an Olympus BX61 transmission white field/fluorescence microscope coupled to a digital acquisition kit (digital camera Olympus DP 71 and Cell F software). In order to make comparisons between treatments, all observations were made using the same low magnification of 20x. For each Frankfurter section, a mosaic images reconstitution was performed. Image analysis software (Image J) was used to quantify the number of fat globules per optical field and the area of each one.

Statistical analysis. Data were analysed using STATISTICA software. Effect of each lever was tested by a one-way analysis of variance (ANOVA). Tukey test was used to test significant differences ($p < 0.05$) among means values.

III. RESULTS AND DISCUSSION

A°) Trial 1. Effect of the initial temperature of ingredients on emulsion physicochemical characteristics.

ANOVA revealed a significant effect of the initial temperature of the ingredients on the lipid oxidation, texture profiles and area of fat droplets ($p < 0.01$). Manufacturing Frankfurters with ingredients at 0°C leaded to a duration of cuttering twice as long as with ingredients at 5°C without any increase of lipid oxidation (Table 2). Lipid oxidation is significantly lower in F 0°C than in C 5°C. The use of ingredients at low temperature reduced the level of oxidation.

Table 2 Effect of process lever on meat emulsions.

Samples at Day 0	C 5°C	F 0°C
Cuttering duration (min)	3 min 15 s	6 min 30 s
TBARS (mg MDA/kg of meat)	$0.70^{a} \pm 0.03$	$0.36^{b} \pm 0.03$
Young modulus	$0.51^{a} \pm 0.03$	$0.77^{b} \pm 0.03$
Shear resistance (N/cm2)	$3.40^{a} \pm 0.23$	$1.64^{b} \pm 0.23$
Rupture energy (J)	$0.099^{a} \pm 0.005$	$0.043^{b} \pm 0.00$:
Mean area of fat droplets (mm^2)	$3.24.10^{-3a}$	$0.634.10^{-3b}$

C 5°C, control frankfurter; F 0°C, Frankfurters made with ingredients at 0°C.

The texture profile of the Frankfurters was affected by the process. F 0°C samples presented higher values of Young modulus than control samples (Table 2). Bañón *et al* (2008) reported that the emulsion texture can be modified by the cuttering duration. They observed an increase of gel strength with increasing chopping duration up to ≈ 7 min, beyond this time an inversion was obtained. The shear resistance and the rupture energy were significantly higher in the samples control than samples F 0°C. Therefore F 0°C samples were firmer and less viscous than the control samples (Table 2). However, this difference in texture profile between two samples (C *versus* F) may be no noticeable by consumers. The sensory evaluation of frankfurters formulated with a konjac-gel, as a fat substitute, revealed no significant difference with control whereas the texture profiles were significantly different between two samples [6]. The microstructure of fat droplets in different Frankfurters is presented in Figure 1. The time of the cuttering operation of ingredients induces large changes of the size of fat droplets (Table 2). An increase of cuttering duration by two induced a decrease of mean area of fat droplets by five (Table 2).

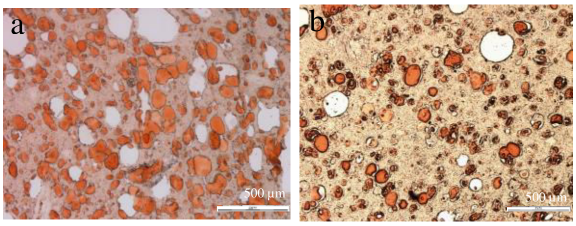

Figure 1 Photomicrograph of transverse sections of Frankfurters (a) Control at 5°C; (b) Frankfurter at 0°C.

5°C is the conventional temperature practiced in industry. With the conventional process, the fat droplets present a mean area from $1.5.10^{-3}$ to 2.10^{-3} mm^2 and a size of 46 µm diameter [8]. Vingerhoeds *et al* (2008) [9] showed a minor effect of variation of droplet size from 0.5 to 6 µm on perception emulsion. However, this study was performed on an emulsion composed of sunflower oil stabilized by whey protein isolate. It is known that droplet size affects the release lipophilic aroma from oil droplets. An increase of diameter of droplet is correlated to an increase in flavours release [10].

A°) Trial 2. Effect of fibers or starch on emulsion physicochemical characteristics.

Dietary fibers or starch are often used in low-fat meat products to counteract the problems caused by fat reduction [4, 11, 12]. Psyllium fibers have been added in Frankfurters for its potential health benefits (*i.e.* hypolipidemic effect, capacity to reduce hyperglycemia and to prevent colon cancer), its emulsifying power and its gelling properties [14]. Psyllium may be used as a carbohydrate-based fat replacer in low-fat food. Tapioca starch was also introduced in Frankfurters, as a fat replacers, to improve sensory properties: flavour and juiciness due to its capacity to retain moisture [12].

Table 3 Effect of formulation lever on meat emulsions.

Samples at Day 0	F/FP	F/TS
TBARS (mg MDA/kg of meat)	$0.33^a \pm 0.03$	$0.58^b \pm 0.03$
Young modulus	$0.60^a \pm 0.12$	$0.64^a \pm 0.12$
Shear resistance (N/cm2)	$3.03^a \pm 0.34$	$4.01^a \pm 0.34$
Rupture energy (J)	$0.075^a \pm 0.006$	$0.121^b \pm 0.006$
Mean area of fat droplets (mm^2)	$1.41.10^{-3a}$	$2.00.10^{-3a}$

F/FP, Frankfurters with ingredients at 0°C + psyllium fibers; F/TS, Frankfurters with ingredients at 0°C + tapioca starch.

Apart the Young modulus variable, the formulation lever induced a significant changes on all parameters by comparison with F 0°C samples ($p < 0.01$) which corresponded to the control samples in trial 2 (Table 2 and 3).

Concerning the lipid oxidation, the Turkey test revealed no significant difference between samples F 0°C and F/FP (Table 2 and Table 3). Hence, the addition of fiber psyllium did not change the lipid oxidation level. This results is in agreement with those obtained by Choi *et al* (2010) [11]. Nonetheless, the lipid oxidation level was significantly higher in samples F/TS than in samples F/FP and F 0°C ($p < 0.05$). Tapioca starch contains some complex sugars which can be involved in stress oxidant. The Frankfurters thermal treatment can induce the glucose auto-oxidation and form an anionic radical which may be able to reduce oxygen into superoxyde radical [15]. The shear force was significantly affected by formulation lever. The samples F/TS presented higher shear force than samples F/FP and the F/FP samples had a shear force superior to samples F (Table 2 and 3). This result showed that the addition of starch or fibers in meat batters leaded to an increase in springiness of Frankfurters. Hughes *et al* (1998) [12] found a higher springiness in the sausages manufactured with tapioca starch. Starch enhances the formation of stronger heat-induced emulsion because starch granules embedded in the protein matrix swell. Unlike to the results of Cofrades *et al* (2008) [13], obtained on emulsions formulated with seaweed fibers, the addition of psyllium fibers did not induce any change in the firmness of the emulsions (Table 2 and 3). This difference can be explained by the nature of fibers and the fiber amount.

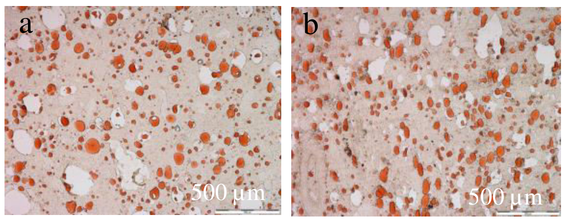

Figure 2 Photomicrograph of transverse sections of Frankfurters (a) Frankfurter made with psyllium fibers (b) Frankfurter made with tapioca starch.

Figure 2 depicts the microstructure of fat droplets in Frankfurters made with psyllium fibers and tapioca starch. The results showed that the formulation of Frankfurters with fibers or starch increases significantly the mean area of fat droplets, in comparison with the samples F 0°C (Table 2 and 3).

Consequently the incorporation of fibers increased the fat droplets size ($0.6.10^{-3}$ for sample F 0°C to 2.00 10^{-3} for sample F/TS). However how this difference may be noticeable by consumers is questioning.

IV. CONCLUSION

This study dealt with the control of the lipid structure in meat emulsions in order to highlight relationships between the food structure and the sensory response of subjects during consumption. For this purpose, a relevant food model of Frankfurters was developed to study the effect of two levers, process and formulation, on the emulsions properties such as the lipid oxidation, the texture profile and the size of fat droplets. This work demonstrated that the process lever, namely the initial temperature of ingredients and therefore the cuttering duration, induced larger changes on the physicochemical characteristics of emulsions than the formulation lever. To evaluate the effect of these emulsion structures on the sensory perception of consumers, a sensory analysis is in progress. This present work forms part of an integrated approach which combines technological, nutritional and organoleptic considerations.

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