Comparison of rheological properties in fatty liver from duck and goose by oscillatory plate-plate rheometer measurements.

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ABSTRACT

Texture of fatty liver, as a multi-parameter attribute, has been examined more and more during the last decade. The instrumental texture analysers used are developed on the analogy of penetration tests to imitate the action of human jaws. In this study a Physica UDS200 rheometer was used, fitted with a MP31 top plate and a Peltier bottom plate.

Rotational rheometer measurements using plate-plate systems seem to represent feasible off-line methods for objective texture characteristics of fatty liver.

INTRODUCTION

Rheological characterisation of food products like fatty liver from force fed goose and ducks, have to be expressed as objective measures. There are many reasons for such measurements. Some reasons may be in order to decide, or achieve a defined quality of the product, to optimize manufacturing processes and as a method of grading.

Special challenges are associated with rheological methods examining temperature sensitive biological fatty products like “foie gras”. Both, the fat content and the fatty acid composition in such products, will influence on rheological properties which will vary even at small temperature changes. Existing laboratory instruments measure accurately and objectively rheological parameters. Since rheological behaviour of food with high fat content is very dependent on temperature variations, this will complicate the feasibility of these methods[1].

Grading of fatty liver from goose and duck all over the world is mainly based on manual examination. This can be considered as a sensory test where the most critical step is the estimation of texture characteristics. The texture is influenced by the tissue structure. It is a complex rheological attribute, which can be detected by several ways; the most important ones being touch/ pressure. Traditionally, in Hungary graders are trained by practical presentations. Studies have shown that the reproducibility of this is relatively poor[2].

The texture of fatty liver, as a multi-parameter attribute, has been examined more and more during the last decade. The instrumental texture analysers used are developed on the analogy of penetration tests to imitate the action of human jaws. In accordance to this, K. Horváth-Almássy and O.Bara-Herczegh[2] demonstrated that a Stevens QTS 25 Texture Analyser could be used to characterise the quality of goose liver. In this study it was concluded that this instrumentation could be an important supplement of traditional grading method. It could help training graders in supervising and being up-to-date.

P. Chartrin et al, 2006[3], used another objective method for texture analysis to evaluate sensory characteristics in duck breast meat. They used a single-blade (Warner-Bratzler) shear test, performed with a universal testing machine (MTS Synergie 200, MTS Systems, Ivry sur Seine, France).

In this study another off-line method for objective texture characteristics using rotational rheometer equipment with plate-plate systems[4] was tested on fatty liver. One important advantage using this equipment is the temperature control system. Accurate temperature control is essential when performing rheological measurements since viscosity generally depends on temperature.

The objectives of this work were as follows;

- To investigate the feasibility of an off-line objective rotational rheometer measurement method using plate-plate systems studying texture characteristics of fatty liver.
- Using an objective rheological measurement method comparing texture differences between fatty liver from goose and duck, which are analysed regarding fatty acid composition.
- Using a method with strict temperature control during performance of rheological measurements; both at constant temperature and during temperature scans from +4-+40^{0}C and back down to +4^{0}C.

MATERIALS AND METHODS

Liver samples

French fatty liver from force fed goose (Maxipalm) and duck (Mule ducks) were used in this study. The animals were slaughtered in a conventional way after 10 hours feed withdrawal. After electric stunning, the animals were bled within 12-15 seconds after cutting the carotids and the jugulars. The samples used were horizontally slices about 25 mm in diameter taken from the superior lobs of the liver. The samples were collected immediately after plucking, frozen in liquid Nitrogen, and stored vacuum-packed in plastic pads at – 20 ºC before analysis. Rheological measurements were carried out after thawing the samples at +4 ºC. The liver sample was then placed as a thin formed "disc" at the bottom plate (the Peltier plate) of the rheometer, Fig. 1.

Instrumental analysis

The MP31 top plate was placed in a bucket containing melting ice, Fig. 2. The Peltier temperature was set to +4 °C. The liver sample was placed on the Peltier plate and gently formed to cover the plate. The MP31, taken from the ice bucket at 0 ºC, was dried with a towel and connected to the rheometer. The MP31 was then lowered very slowly squeezing the liver sample gently to obtain the desired plate – plate clearance of 2 mm. The excess liver was then removed from the rim of the MP31, Fig. 1.

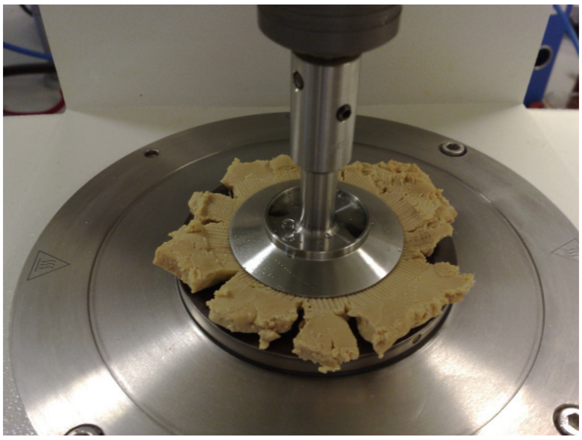

Figure 1: Liver sample prior to removal of excess material. Gap 2 mm.

Experimental set-up

A Physica UDS200 rheometer (Paar Physica, Anton Paar, Germany, 2003) fitted with a MP31 top plate and a Peltier bottom plate was used. The instrument was programmed to perform controlled strain amplitude sweeps from approximately 0.02% strain to 2% strain at 10 Hz. The instrument was also programmed to perform temperature scans at 0.1 % strain at 10 Hz from +4 °C to +40 °C, and back down again to +4 °C. The gap between the plates was constant at 2 mm during the study.

Figure 2: MP31 top plate placed in melting ice.

RESULTS

Table 1, 2, 3 and 4 reports the chemical composition of the geese (Maxipalm) and duck (Mule duck) fatty livers.

The six main fatty acids in livers from goose and duck are significant different regarding the amount of each acid in the two species; $p < 0.001$. One-way Analysis of Variance ANOVA, Minitab, was used as statistical test method for this investigation. Using Minitab, General Linear Model, it could also be concluded that the sum of the 6 main fatty acids (C14, C16, C16:1, C18, C18:1 and C18:2) in livers from goose and duck were significant different; $p < 0.001$. The results from the strain sweep tests with duck and goose liver are shown in Fig. 3 and Fig. 4. The results from the temperature scans are shown in Fig. 5 and Fig. 6.

Table 1. Chemical composition and weight of goose fatty livers (n = 72).

Constituent	Range (%)	Average
Lipids	41.90-64.80	56.84
Protein	6.32-11.90	8.22
Ash	0.05-0.59	0.35
Dry matter	61.41-74.52	68.64
Weight (g)	535-1350	943

Table 2. Chemical composition and weight of duck fatty livers (n = 147).

Constituent	Range (%)	Average
Lipids	29.00-61.80	51.06
Protein	5.39-15.07	8.44
Ash	0.13-0.67	0.40
Dry matter	48.74-72.14	64.07
Weight (g)	204-933	525

Table 3. Percentages of main fatty acids present in goose fatty livers (n = 72)

Fatty acid	Range (%)	Average
C14	0.32-0.81	0.51
C16	18.95-34.26	25.43
C16:1	0.99-3.05	1.98
C18	10.03-22.38	14.48
C18:1	38.30-73.82	55.64
C18:2	0.27-0.92	0.44

Table 3. Percentages of main fatty acids present in duck fatty livers (n = 147)

Fatty acid	Range (%)	Average
C14	0.28-1.21	0.71
C16	17.61-29.26	23.64
C16:1	1.46-5.59	2.43
C18	8.69-24.15	16.97
C18:1	46.86-60.13	53.19
C18:2	0.70-1.87	1.22

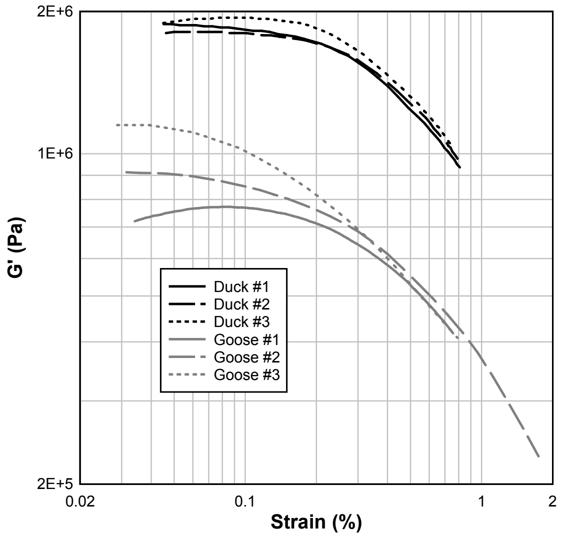

Figure 3: G' versus strain for duck- and goose liver at +4 °C.

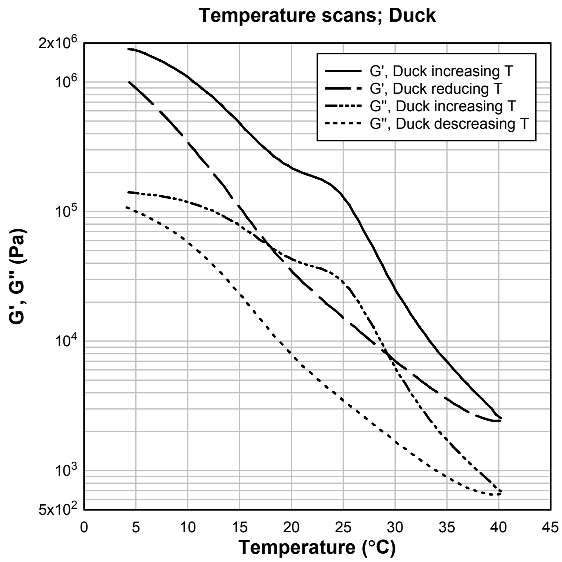

Figure 5: G'and G'' versus temperature for duck liver.

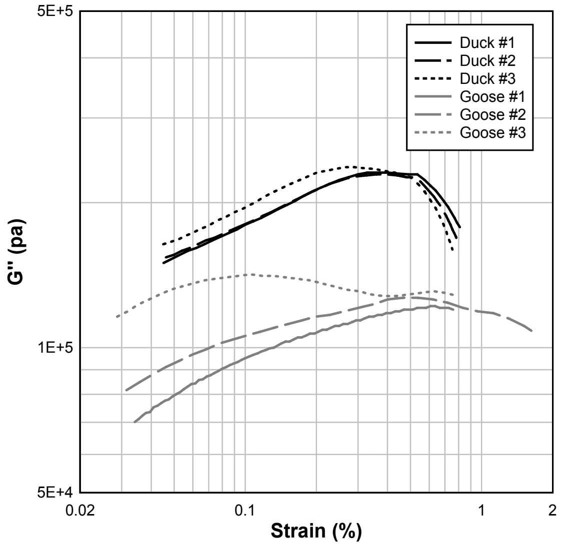

Figure 4: G'' versus strain for duck- and goose liver at +4 °C.

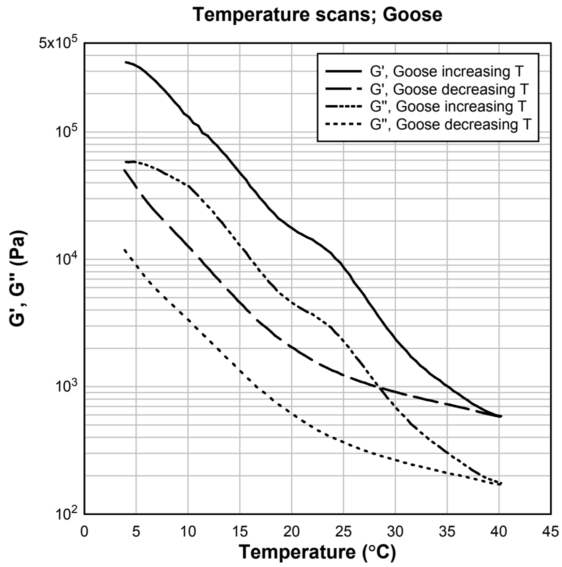

Figure 6: G'and G'' versus temperature for goose liver.

G' : Storage modulus describes elastic properties.
G'': Loss modulus describes viscous properties.

DISCUSSION

Fig. 3 and 4 illustrate the feasibility using an objective rheological measurement method like rotational plate-plate systems, to study texture characteristics of fatty liver. The figures also indicate that the texture of duck liver is stiffer than the liver from goose. An explanation of this phenomenon may be due to the fact that the content of saturated fat is significant higher in the fatty liver from duck compared to fatty liver from goose. Regarding stearic acid (C18), Table 4 shows that the content in liver from duck is about 17%, while the content of C18 in liver from goose is about 14.5%, see Table 3.

C18 has the highest melting point of the studied fatty acids in the livers. It melts at about 69.60 °C, and contributes more to stiffness in livers at lower temperatures than the other saturated fatty acids (C14 and C16). This may be a rational explanation why duck livers seem stiffer than the goose livers in this study.

Using the Physica UDS200 rheometer, the measurements are performed at accurate temperature (+4°C). This is essential when performing rheological measurements since viscosity generally depends on temperature.

Regarding strain before structural damage, Fig. 3 and 4 indicate that duck liver withstands a strain of 0.2% before structural damage. This is not the case for goose liver.

The repeatability of the duck samples was better than the goose samples. The repeatability of goose liver is poor at low values of strain, but it seemed to improve with increased strain, see Fig. 3 and 4.

The moduli of both duck and goose liver decreased with increasing temperature in the temperature range +4 – +40 °C, see Fig. 5 and 6. The temperature range was selected from the point of view that +4 °C is a normal storage temperature for "foie gras" in the shops. While a temperature of +40 °C represents a temperature above the normal body temperature of the bird, at which most of the fat should be melted.

CONCLUSIONS

The conclusions from this study can be summarized as follows:

- Duck liver is significantly stiffer than goose liver.
- Duck liver seems to exhibit some type of linear viscoelastic range while goose liver does not.
- Duck liver can withstand a strain of 0.2% before structural damage, while goose liver does not seem to withstand any deformation without damage.
- The moduli of both duck and goose liver decrease with increasing temperature in the range +4 – +40 °C, and hysteresis are observed.
- Care must be exercised when setting tests in plate-plate rheometers if sample is only heated or cooled from below.
- The rotational rheometer measurements confirm in an objective way the assumption that goose liver is significantly stiffer than duck liver (based on the analysed fatty acid composition of the livers).
- The study indicates that the off-line oscillatory plate-plate rheometer measurement can be useful in grading fatty livers and similar products according to given quality parameters.

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