Comparison of Texture Analysis of Fatty Liver from Duck and Goose Using an Oscillatory Plate-Plate Rheometer and a Texture Profile Analyser

Elling-Olav Rukke[1], Olga Lothe[1], and Reidar Barfod Schüller[1]

[1] Department of Chemistry, Biotechnology and Food Science, Norwegian University of Life Sciences, P.O.Box 5003, N-1432 Ås, Norway

ABSTRACT

In recent years there has been a trend towards a more fundamental approach to food-texture measurement. This usually involves attempts to relate textural characteristics of foods to well-defined physical properties.

In this study we compared measurements from a Physica UDS200 rheometer and a TA-HDi Texture Profile Analyser (TPA) on fatty liver from goose and duck. The UDS rheometer was 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. But in many cases such measurements have limitations regarding information about specific sensoric-rheological characteristics of interest.

To compare the rotational rheolgical measurement results, a TPA two bite test was used. The texture profile analyser seemed even more feasible to characterize rheological parameters in fatty liver from goose and duck; especially regarding hardness and gumminess.

INTRODUCTION

In a previous study[1] it was concluded that off-line oscillatory plate-plate rheometer measurement can be useful in grading fatty livers and similar products according to given quality parameters.

The challenges associated with this approach to texture studies arise from the usually complex- and often non-uniform structure of most natural and manufactured foods. Many physical properties of food change with time and vary according to conditions of storage. Such properties usually vary from point to point within a sample of food. Very few foods exhibit true elastic, viscous or plastic behaviour[2].

Rheological characterisation of food products like fatty liver from force fed goose and ducks, have to be expressed as objective measures. Both, the fat content and the fatty acid composition in such products, influence on rheological properties which will vary even at small temperature changes.

Since rheological behaviour of food with high fat content is very dependent on temperature variations, this will complicate the feasibility of these methods[3].

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 methods; 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[4].

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, Horváth-Almássy and Bara-Herczegh[4] 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.

Chartrin et al.[5] 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 two off-line measurement methods for objective texture characteristics of fatty liver were compared. One method using rotational rheometer equipment with plate-plate systems[6], and the other method using a Texture Profile Analyser. One important advantage using the plate-plate 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 and compare feasibility of two off-line objective rheological instruments studying texture characteristics of raw fatty liver; - using a rotational rheometer instrument equipped with a plate-plate system and a texture profile analyser (TPA).
- Using an objective rheological measurement method to unveil texture differences between raw fatty liver from goose and duck with almost the same chemical composition.
- Investigate connections between rheological measurements and chemical analyses of raw fatty livers regarding fat content and fatty acid composition.

MATERIALS AND METHODS

Liver samples

French fatty liver from force fed goose (Maxipalm) and duck (Mule ducks) were used in this study. The samples used were horizontal slices about 25 mm in diameter taken from the superior lobes of the liver. The samples were collected immediately after plucking, frozen in liquid Nitrogen, and stored vacuum-packed in plastic pads at –20ºC before analysis. Rheological measurements were carried out after thawing the samples in the plastic pads at +4ºC.

Instrumental analysis

The MP31 top plate was placed in a bucket containing melting ice. 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 0ºC, 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[1].

All the bite-size pieces of fatty liver were tempered and tested at +4ºC on the Texture Profile Analyzer (TPA). The samples were covered with a thin plastic film to avoid attachment of fatty liver on the Ebonite Cylinder, Fig. 1.

The TPA - test settings;

Pre-test speed: 2.0 mm/s, test speed:1.0 mm/s, post-test speed: 2.0 mm/s, distance: 5.0 mm, trigger type: Auto, data acquisition rate: 200 pps.

Experimental set-up

The 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 gap between the plates was constant at 2 mm during the study.

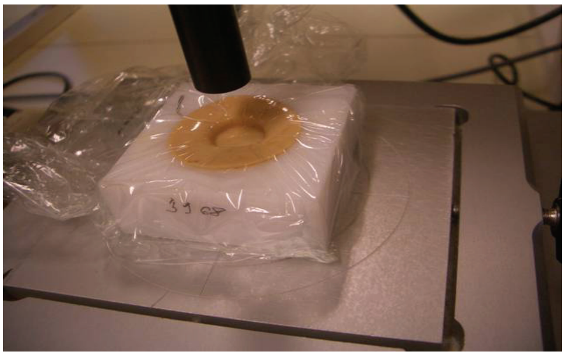

Figure 1. TPA sample covered with plastic film. Probe smaller than sample.

The Texture Profile Analyser TA-HDi TPA (Stable Micro Systems, United Kingdom, 1998) equipped with a data computing programme called Texture Expert Exceed was programmed to carry out controlled two-bite tests. The PO.5 ½" Dia Ebonite Cylinder was used in all the experiments which were repeated three times for each sample.

RESULTS

Tables 1-8 report 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 significantly 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; nomenclature in accordance to reference 7) in livers from goose and duck were significantly different; $p < 0.001$.

The results from the strain sweep tests with duck and goose liver are shown in Fig. 2. The results from the TPA two bites tests are shown in Figs. 3-9.

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

Constituent	Range (w%)	Average (w%)
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 (w%) and weight (g) of 5 random sampled goose fatty livers used in this study ($n_{total} = 72$).

	Goose number				
Const.	486	651	1012	1022	1037
Lipids	64.93	58.35	57.58	57.79	55.17
Protein	7.16	7.41	8.47	7.16	8.02
Ash	0.36	0.37	0.45	0.29	0.39
Dry m.	72.63	71.78	67.96	69.77	66.87
Weig.	1129	963	750	1075	922

Table 3. Chemical composition (w%) and weight (g) of duck fatty livers (n = 147).

Constituent	Range (w%)	Average (w%)
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

One-way Analysis of Variance ANOVA, Minitab, was also used as statistical test method to investigate the first of the three repeated TPA measurements between the liver samples of duck and geese. Using 5% level of significance the ANOVA was clearly significant regarding hardness ($p<0.05$) and gumminess ($p<0.05$). The ANOVA regarding cohesiveness, chewiness and springiness were not found to be significant using any "practical" level of significance.

Table 4. Chemical composition (w%) and weight (g) of 5 random sampled duck fatty livers (n_{total} = 147).

	Duck number				
Const.	3489	3619	3758	3943	4020
Lipids	52.80	46.31	52.80	53.70	57.68
Protein	8.11	15.07	8.05	8.11	6.89
Ash	0.41	0.48	0.44	0.30	0.21
Dry m.	63.64	59.27	65.05	66.41	69.05
Weig.	602	326	519	735	712

Table 5. 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 6. Percentages of main fatty acids present in 5 random sampled goose fatty livers (n_{total} = 72).

	Goose number				
FA	486	651	1012	1022	1037
C14	0.57	0.44	0.55	0.42	0.48
C16	25.31	23.28	26.98	22.46	24.05
C16:1	2.48	1.58	1.78	2.05	2.14
C18	13.17	15.75	14.13	13.12	13.75
C18:1	56.99	57.10	54.74	60.40	57.86
C18:2	0.43	0.18	0.59	0.27	0.47

Table 7. 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

Table 8. Percentages of main fatty acids present in 5 random sampled duck fatty livers (n_{total} = 147).

	Duck number				
FA	3489	3619	3758	3943	4020
C14	0.41	0.80	0.61	0.55	0.72
C16	18.06	27.28	21.17	20.59	23.62
C16:1	1.66	3.54	2.16	2.13	2.29
C18	17.36	14.03	17.51	15.99	15.85
C18:1	59.69	51.56	54.39	59.52	54.35
C18:2	1.11	1.33	1.37	1.28	1.48

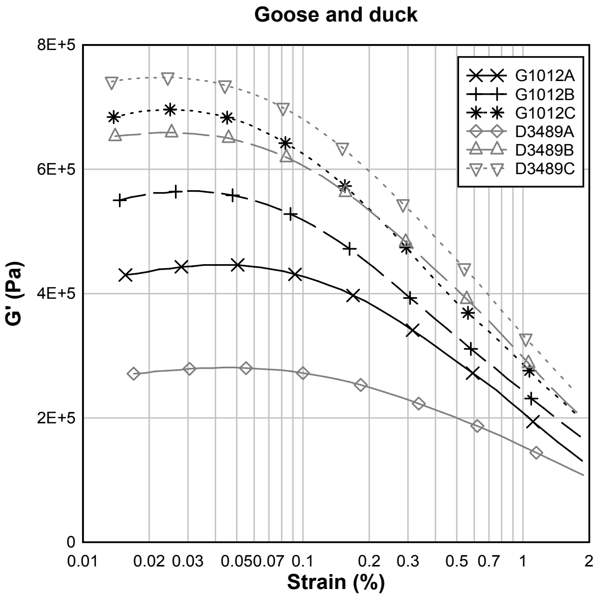

Figure 2. Storage modulus G' (elastic properties) versus strain for duck- and goose liver at +4°C using an oscillatory plate-plate rheometer.

DISCUSSION

Fig. 2 shows results using the rotational plate-plate equipment describing texture characteristics of the fatty liver from goose and duck. The rotational measurements indicate that the texture of the tested fatty liver is almost the same. This result is also in a way expected with reference to fat content and fatty acid composition from Tables 2, 3, 7 and 8. But such a conclusion seems both premature, and incorrect without

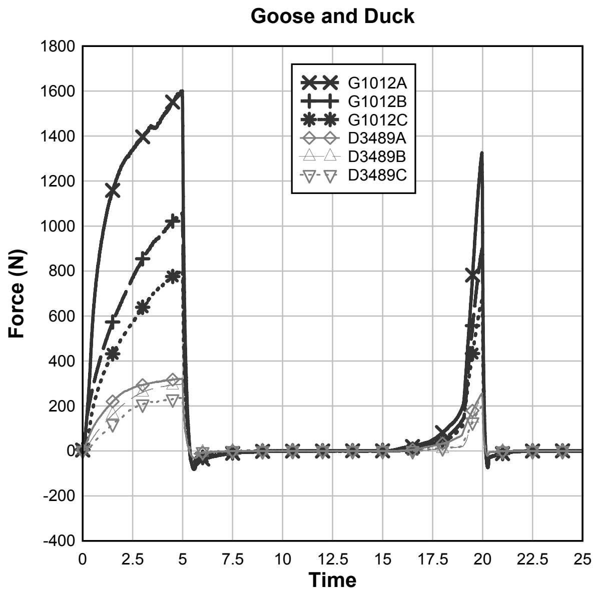

Figure 3. A typical TPA plot highlighting force versus time for one goose - and one duck liver, three two-bite TPA repetitions of each sample at +4°C.

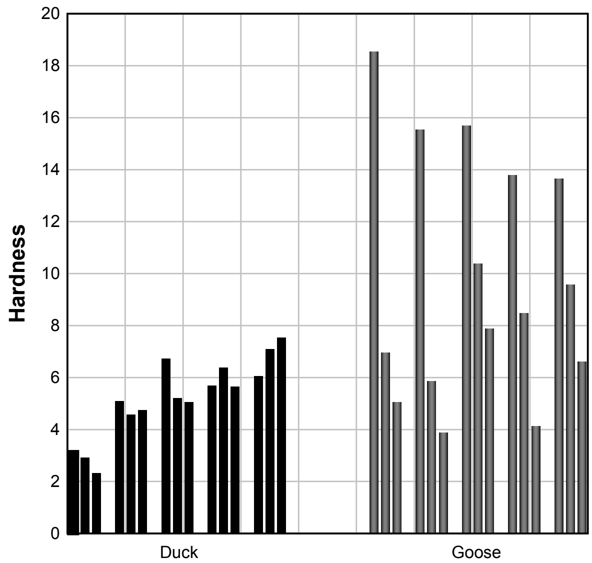

Figure 5. Hardness for duck (n_D=5)- and goose liver (n_G=5), three two-bite TPA repetitions of each sample at +4°C.

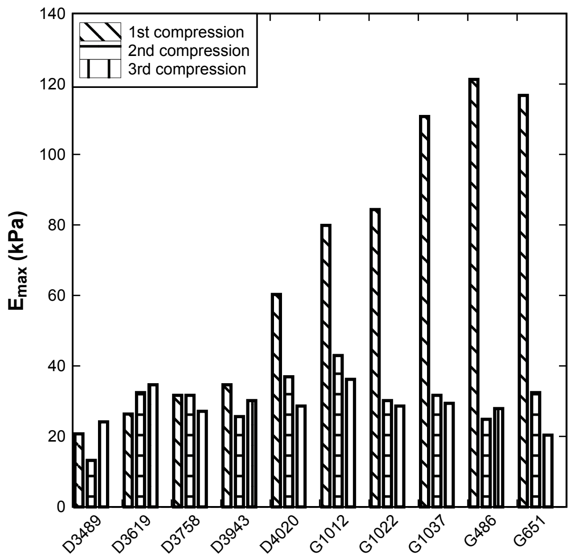

Figure 4. Maximum elastic modulus for duck (n_D=5)- and goose liver (n_G=5), three two-bite TPA repetitions of each sample at +4°C.

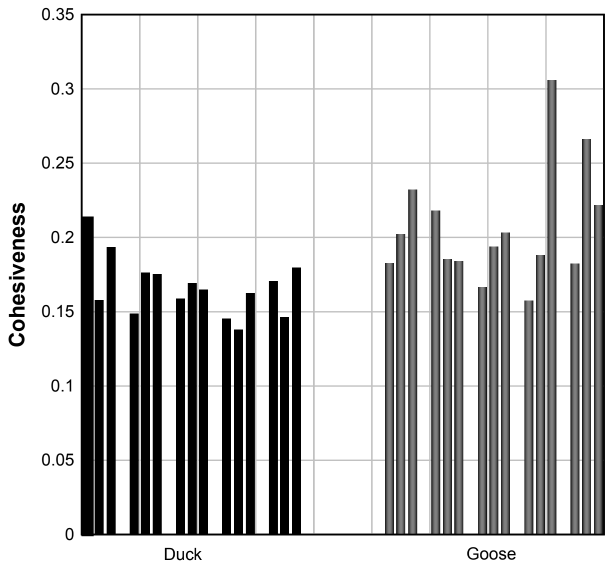

Figure 6. Cohesiveness for duck (n_D=5)- and goose liver (n_G=5), three two-bite TPA repetitions of each sample at +4°C.

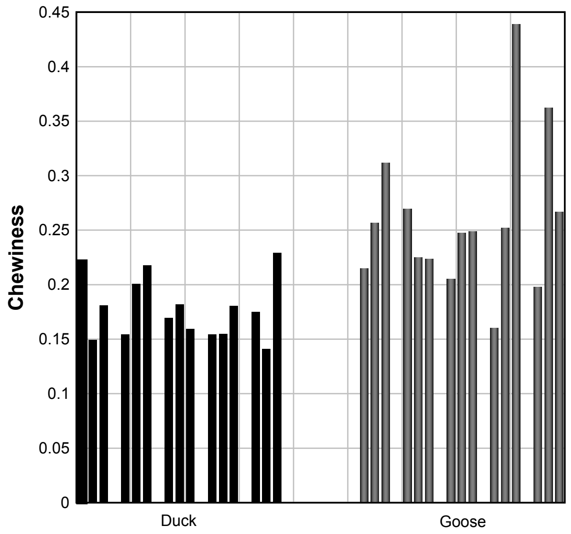

Figure 7. Chewiness for duck (n_D=5)- and goose liver (n_G=5), three two-bite TPA repetitions of each sample at +4°C.

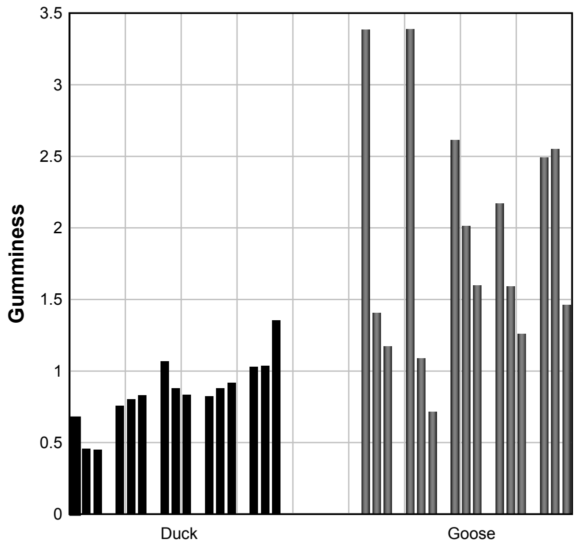

Figure 8. Gumminess for duck (n_D=5)- and goose liver (n_G=5), three two-bite TPA repetitions of each sample at +4°C.

further investigation of the livers. This is also in contrast to previous reported results[1], which indicated that the elastic modulus of duck liver was higher than the liver from goose. This was 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; Tables 5 and 7.

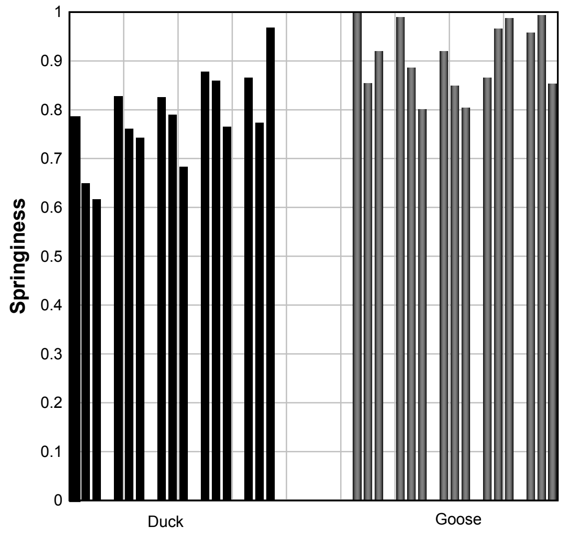

Figure 9. Springiness for duck (n_D=5)- and goose liver (n_G=5), three two-bite TPA repetitions of each sample at+4°C.

To get more information about this phenomenon, we continued studying the livers by using the TPA instrument. This instrument gives a satisfactory measure of the extent of deformation of the samples. The instrument imitates the highly destructive process of mastication in the mouth. But compared to the Physica instrument it is more challenging maintaining constant temperature during the time of measurement, which of course is essential when performing rheological measurements.

Fig. 3 illustrates a typical TPA curve; the first compression cycle (first bite) and the second compression cycle (second bite) for three repetitions. The graphs indicate that goose livers at +4°C have higher deformation values when imitating the highly destructive process of mastication in the mouth, compared to duck livers. The variations between the deformation values to break the liver samples are also larger between the three repetitions of goose liver compared to duck liver. This seems also reasonable since the goose fatty livers have both higher content of dry matter and fat (Tables 1 and 2), compared to the livers from duck (Tables 3 and 4).

Fig. 4 demonstrates the elastic modulus of the liver samples. The goose livers seem to exhibit a higher elastic modulus with regard to the first repetition of all measurements. The maximum E_{max} can be calculated from the following equation

$$E_{\max} = \left\{ \frac{d(F/A)}{d\left(\frac{\Delta L}{L_\circ}\right)} \right\} = \left(\frac{d\sigma}{d\varepsilon}\right)_{\max} \quad (1)$$

representing the maximum slope of the curve during initial compression. F is applied force, A is the cross-sectional area, L_0 is unstressed length (initial length), and ΔL is change in length caused by compression.

Regarding hardness which is defined as maximum peak force during first compression cycle (first bite), the TPA results in Fig. 5 indicate that goose livers starts out to be rather firm at the first compression cycle. But when repeating the test, the firmness decreases for all the tested samples. This is in contrast to the duck livers which seem to behave more or less unchanged during the three repeated two bite tests. This indicates that goose livers being a solid food, become more or less semisolid during sensory mastication. Using 5% level of significance the ANOVA is clearly significant regarding hardness of the first bite test between the tested samples of duck and geese.

The cohesiveness results show the rate at which the fatty livers disintegrate under mechanical action. The results in Fig. 6 indicate that the cohesiveness seems to increase for most of the repeated two bite tests of goose liver. The cohesiveness parameter varies between 0.16-0.31 for the goose livers and between 0.14-0.22 for duck livers. But this difference is not confirmed using the ANOVA test with 5% level of significance.

Chewiness is measured in terms of energy required to masticate the livers samples. Fig. 7 shows that this parameter varies between 0.16-0.44 for goose liver and between 0.14-0.0.23 for duck liver. The ANOVA test of the first repeated measurements for all the samples indicates no significance using any "practical" level of significance. By the way, chewiness is difficult to measure precisely because mastication involves compressing, shearing, grinding, tearing and cutting.

Gumminess characterise semisolid food with a low degree of hardness and a high degree of cohesiveness. Fig. 8 show that the gumminess values for the first two bite tests vary from 2.2-3.4 for goose, and from 0.5-1.3 for duck. This means that goose liver behave more like a semisolid food after the first bite test, compared to the duck livers which seem to react more like a solid food. This difference is also confirmed by the ANOVA test, when using 5% level of significance.

Fig. 9 illustrates the springiness of the liver samples. It is related to the height that the food recovers during time that elapses between the end of the first bite and the start of the second bite. There are no units for this parameter which originally was called elasticity.

CONCLUSIONS

The conclusions from this study can be summarized as follows:

- Duck liver withstands external forces like a TPA two bite test which imitates the action of human jaw almost without structural damage, while goose liver does not.
- The repeatability of the duck samples using the TPA test was better than for goose samples.
- Goose liver seems to behave more like a semi solid food than a solid food, while duck liver does not.
- The TPA test was able to separate between textural parameters like

hardness and gumminess while oscillatory plate-plate did not. One-way Analysis of Variance ANOVA, Minitab, was used as statistical test method to investigate this at a level of 5% significance.

- Care must be exercised when setting tests in plate-plate rheometers if sample is only heated or cooled from below.
- The study indicates that both the Texture Profile Analyser and the off-line Oscillatory Plate-Plate Rheometer can be useful in grading fatty livers and similar products according to given quality parameters. The TPA test performs better regarding unveiling important texture characteristics when samples seem to have more or less the same chemical composition. In this case it is demonstrated especially regarding fat content and fatty acid composition of the livers.

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REFERENCES

1. Rukke, E.O., Fernandez, X. and Schüller, R.B. (2008), "Comparison of rheological properties in fatty liver from duck and goose by oscillatory plate-plate rheometer measurements", *Ann. Trans. Nordic Rheol. Soc.*, **16**, 57-62.

2. Brennan, J.G. (1994), "Food texture measurement", Developments in Food Analysis Techniques 2, 1-78.

3. Salas-Bringas, C., Jeksrud, W.K. and Schüller, R.B. (2006), "A new on-line process rheometer for highly viscous food and animal feed materials". *J. Food Eng.,* **79**, 383-391.

4. Horváth-Almássy, K. and Bara-Herczegh, O. (2006), "Assessment of fatty goose liver grade by texture analysis", *Acta Alimentaria,* **35**(4), 363-372.

5. Chartrin, P., Méteau, K., Juin, H., Bernadet, M.D.; Guy, G., Larzul, C., Rémington, H., Mourot, J., Duclos, M.J. and Baéza, E. (2006), "Effects of intramuscular fat levels on sensory characteristics of duck breast meat", *Poultry Science*, **85**, 914-922.

6. Schüller, R.B. and Salas-Bringas, C. (2007), "Fluid temperature control in rotational rheometers with plate-plate measuring systems", *Ann. Trans. Nordic Rheol. Soc.*, **15**, 159-163.

7. Gunstone, F.D., Harwood, J.L. and Padley, F.B. (1986), "The Lipid Handbook", Chapmann and Hall Ltd, The University Press, Cambridge, ISBN 0 412 24480 2.