

GOOSE FATTY LIVER COMPOSITION AS RELATED TO THE DEGREE OF STEATOSIS, NUTRITIONAL AND TECHNOLOGICAL TREATMENTS, AND A SIMPLIFIED METHOD FOR QUALITY ESTIMATION

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SUMMARY

A simple procedure for the quantitative determination of goose fatty liver quality is described. The procedure deals with fat release at 100°C/24 h (FR) or fat and water release during pasteurization at 70°C/2 h (liquid release LR). The exudates obtained by the different heat treatments were closely correlated ($r = 0.882$). The mean FR determined on 227 livers (varying widely in weight) was 19.4 p. 100 with a standard error of ± 0.8 . The LR was approximately 75 p. 100 of the FR and was predictable from FR ($Y = 0.9 \times - 3.29$). The FR was positively related to the fat ($r = 0.72$) and negatively to the protein ($r = - 0.62$) and phosphorus ($r = 0.61$) concentrations. Protein and phosphorus supplementation to the diet force-fed to the geese, increased the concentration of these materials in the livers and consequently decreased the FR. Cold storage at $- 20^\circ\text{C}$ during 1 month did not affect significantly the FR and LR of liver samples. Cholesterol and iodine number were not related to FR.

The possibilities and limitations of the suggested procedure are discussed.

INTRODUCTION

Liver composition is considerably altered in force-fed obese geese. Total lipid concentration increases up to ten-fold and protein concentrations decreases to about 50 p. 100 of the initial value. The changes in cholesterol and lipid phosphorus concen-

trations are slight: cholesterol increases while lipid phosphorus decreases (LECLERCQ *et al.*, 1968; SZYLIT *et al.*, 1968; NIR and PEREK, 1971; BALDISSERA NORDIO, 1971). Up to now most of the works dealing with the chemical composition of fatty livers from crammed geese were conducted on a limited number of livers. The present work is a study of the chemical composition of the steatic liver, and the relationship between the determined variables and the liver quality. The study was carried out with a large number of livers varying widely in their degree of steatosis. It was intended to test the validity of a proposed simplified method for estimating one aspect of the quality of goose fatty livers. Until now, liver grading has been done according to weight, consistency appearance and texture. The criteria requested generally for Grade A livers are the absence of bile and blood stains or clots, weight ranging from 400-950 g, light and uniform coloration, a plastic consistency and smooth texture. The above standards do not answer all the needs of the goose-liver manufacturers. During the process of pasteurization or sterilization, livers release various amounts of fat. Fatty livers differ widely in this respect. The producer is interested mainly in livers which release minimal amounts of fat during this process. The objective of the present work was to secure information on the magnitude of fat release during heating, and the relationship to parameters such as liver-weight, composition, degree of steatosis and other values.

MATERIALS AND METHODS

The livers tested in the present study were obtained from geese grown on the Akko Experiment Farm and on a private farm. The geese, aged 3-6 months at the start of cramming, were from various breeds and crosses: *Landes, Local* (NIR and PEREK, 1971), *Rhines* × *Landes*, *Local* × *Landes*, and *Landes* × *Local*. The data from the different breeds, crosses and ages were pooled since the genetic source or the age of the geese showed no effect on the liver composition. The geese were force-fed with cooked maize supplemented with salt, vitamins and 1 p. 100 oil (NIR and PEREK, 1971) or with a pelleted feed (1). Cramming lasted 25-32 days. After slaughter the geese were kept in a refrigerated room for 24 h. The livers were then removed and weighed. Liver samples were sent to the laboratory in plastic bags on crushed ice.

Chemical determinations

Water content and fat release (FR) by heat were determined on samples weighing 3.5-4.5 g. The samples were placed on steel sieves in tared petri dishes and kept in an oven at 100°C/24 h. They were then transferred to a desiccator and weighed for the determination of moisture. The liver sample was then removed and the petri dish weighed again for the determination of fat released. Fat and water release (liquid release = LR) during pasteurization were determined in closed glass jars in an oven at 70°C/2 h. Total fat, cholesterol, lipid phosphorus, total phosphorus and nitrogen were determined by the procedures described by NIR and PEREK (1971). Iodine number was determined on the ether extracts according to AOAC (1960).

(1) Yellow maize, 87.2; heated soya-bean meal, 10; soya-bean oil, 0.6; CaHPO₄, 1; NaCl, 0.5; NaHCO₃, 0.3; vitamins and microelements, 0.4 p. 100. Certified to supply per ton mash: vit. A, 4 500 000 I.U.; vit. D₃, 450 000 I.U.; vit. E, 2 000 I.U.; vit. K, 1 g; riboflavin, 3 g; pantothenic acid, 6 g; niacin, 15 g; pyridoxine, 1 g; vit. B₁₂, 6 mg; choline chloride, 100 g; manganese, 16 g; zinc, 10 g; copper, 0.5 g; iron, 5 g; iodine, 250 mg.

RESULTS

The relationships between FR and composition of samples from six different locations of the liver, to the FR and composition of the whole liver

Eight livers were used in this study. Samples were drawn with a 1.2 cm diam. cork driller from the extremities and the middle of each lobe as shown in figure 1. One half of each sample was used for moisture and fat release and the other half

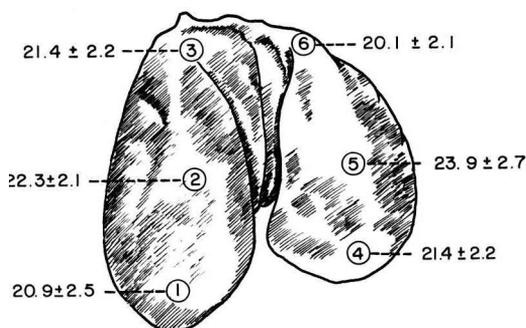


FIG. 1. — Location of the samples removed for the determination of the relationship between whole liver and sample composition. Numbers in circles indicate the samples' location. Figures show the mean SE of the fat released (100°C/24 h) by samples from each location (means of 8 livers).

for chemical determinations. The results are shown in table 1. The samples released about 2 p. 100 more fat than the whole livers. Moisture released by whole livers was weight dependent; small livers released more than big ones and no relationship was found between the moisture content in samples and the moisture released by the whole livers. The fat released by the samples drawn from the center of the lobes was higher than the amount released by the samples drawn from the extremities (not statistically significant difference) (fig. 1).

Fat release from samples obtained from different locations was highly correlated to the values obtained for the whole liver (table 1). Total fat, total protein, lipid phosphorus and cholesterol in each sample were highly correlated to the mean values of the six samples obtained from each liver. The subsequent work was done on samples obtained from location 3 (fig. 1), because it was most convenient to draw samples from this location as it causes the least damage to the liver, and because the correlation coefficient between this sample and the whole liver obtained for FR was the highest.

The effect of heat duration on FR (fig. 2)

The amount of FR reached a maximum after 2 h in all the samples. The samples which released the highest amounts of fat attained this peak after 0.5 or 1 hour. The correlation coefficients between the FR during 0.5 or 1, 2, and 4 versus 24 h were very high ($r \geq 0.97$). It can be seen that generally the FR was related to liver weight

TABLE I

Chemical composition, water and fat released by whole livers and samples from different locations* and the correlation coefficients (r) of the variables between livers and their samples

| | Mean \pm SEM ⁺ | Range |
|----------------------------------|-----------------------------|-------------|
| Liver weight (g) | 927 \pm 71 | 557 — 1 172 |
| <i>Samples' mean</i> | | |
| Moisture (p. 100) | 35.2 \pm 0.8 | 32.2 — 40.8 |
| Protein (p. 100) | 6.5 \pm 2.8 | 5.5 — 8.4 |
| Fat (p. 100) | 53.7 \pm 1.4 | 46.1 — 60.1 |
| Lipid phosphorus (mg/100 g) | 74 \pm 4.3 | 61 — 103 |
| Cholesterol (mg/100 g) | 740 \pm 38 | 558 — 974 |
| Fat release (p. 100) | 21.9 \pm 2.1 | 9.3 — 29.3 |
| <i>Whole livers</i> | | |
| Moisture release (p. 100)..... | 26.7 \pm 1.2 | 26.1 — 33.3 |
| Fat release (p. 100) | 19.7 \pm 2.1 | 8.3 — 28.5 |

| | Correlation coefficients (r) | | | | | |
|------------------------|------------------------------|------|------|------|------|------|
| | Sample locations* | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 |
| <i>Liver</i> | | | | | | |
| Fat release** | .792 | .910 | .990 | .845 | .932 | .984 |
| Fat | .754 | .875 | .928 | .883 | .904 | .853 |
| Protein..... | .985 | .901 | .980 | .895 | .862 | .875 |
| Lipid phosphorus | .615 | .951 | .905 | .952 | .852 | .906 |
| Cholesterol | .845 | .929 | .863 | .928 | .853 | .786 |

+ SE of the mean.

* See (fig. 1).

** FR was determined on whole livers while other values were obtained by averaging the values of the 6 samples. All the values are highly significant, P < 0.01.

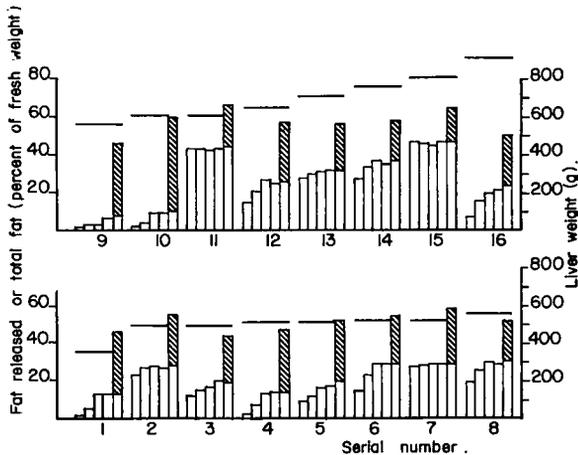


FIG. 2. — Fat released from liver samples following different periods of heat treatment (100°C). Columns represent the amount of FR from the sample following 0.5, 1, 2, 4 and 24 h. Barred columns represent total fat in the sample. Horizontal lines represent the liver weight from which the sample was removed.

TABLE 2

Weight, composition and fat released by heat from geese fatty livers and the correlation coefficients (r) between the variables

| | Mean ± SEM ⁺ | Range | Correlation coefficients | | | | | | | | | | |
|--|-------------------------|-------------|--------------------------|----------|--------------|-----------|---------------|---------|------------|-------------|--|--|--|
| | | | Liver weight | Moisture | Fat released | Total fat | Total protein | Lipid P | Phosphorus | Cholesterol | | | |
| Liver weight, g (227) × ... | 659 ± 11.0 | 350 — 1 350 | | | | | | | | | | | |
| Moisture, p. 100 (227) ... | 37.1 ± 0.3 | 25.2 — 50.1 | — .37** | | | | | | | | | | |
| Fat released, p. 100 (227) ... | 49.4 ± 0.8 | 1.0 — 46.2 | .50** | — .75** | | | | | | | | | |
| Total fat, p. 100 (227) ... | 54.2 ± 0.5 | 39.3 — 77.0 | .41** | .73** | | | | | | | | | |
| Total protein, p. 100 (227) ... | 8.47 ± 0.09 | 5.9 — 13.1 | — .32** | .46** | — .62** | | — .47** | | | | | | |
| Lipid phosphorus, mg/100 g (88) | 77 ± 2.2 | 32 — 133 | .047 | .003 | — .135 | .074 | .45** | | | | | | |
| Total phosphorus, mg/100 g (184) | 127 ± 1.7 | 75 — 196 | — .34** | .45** | — .61** | — .45** | .75** | .47** | | | | | |
| Cholesterol, mg/100 g (88) | 777 ± 20.7 | 422 — 1 236 | .17 | .03 | .04 | — .02 | — .14 | — .07 | — .11 | | | | |
| Iodine number (43) | 54.8 ± 0.7 | 47.2 — 70.9 | — .18 | .25 | — .13 | — .36** | — .15 | — .36* | — .16 | | | | |

⁺ Standard error of the mean.

× Number of samples.

* Statistically significant, P < 0.05.

** P < 0.01.

and to the total fat concentration ; however, some livers deviated from this general trend.

All the determinations of FR were made subsequently on samples heated for 24 h.

*Liver weight, sample composition,
FR and relationships between these values*

Both weights of livers and their composition varied over a wide range (table 2). The average weight of the livers was 659 g, with an average concentration of 37.1 p. 100 moisture, 54.2 p. 100 fat, and 8.17 p. 100 protein. The mean FR was 19.4 p. 100, *i. e.*, about 35 p. 100 of the total fat content and its variation was high, as was its range (1.0 p. 100-46.0 p. 100). Lipid phosphorus, total phosphorus, cholesterol and iodine number were 77, 127, 777 mg/100 g and 54.8, respectively. The lipid phosphorus was about 60 p. 100 of the total phosphorus.

The correlation coefficients between the different variables are shown in table 2. Liver weights were found to be positively correlated to FR and total fat, and negatively correlated to moisture, protein and total phosphorus.

A high correlation was found between total protein and total phosphorus. The close relationship between these two variables explains the similarity of the correlation coefficients between each one of them and liver weights, moisture content, FR, total fat and lipid phosphorus.

Cholesterol concentration was not correlated to any of the variables tested.

The Iodine Number was correlated negatively to total fat and to lipid phosphorus concentrations only.

*Relationship between fat release (FR) at 100°C/24 h and liquids
release (fat + water) (LR) at 70°C/2 h (fig. 3)*

This experiment was carried out on samples from 60 livers in order to determine the relationship between the exudates of different liver samples, following a treatment common in industry (pasteurization) and the proposed procedure (desiccation at 100°C/24 h). The levels of exudates following 100°C/24 h or 70°C/2 h were highly correlated (fig. 3). It was, therefore, concluded that FR could represent the relative amount of exudate discharged by different heat treatments.

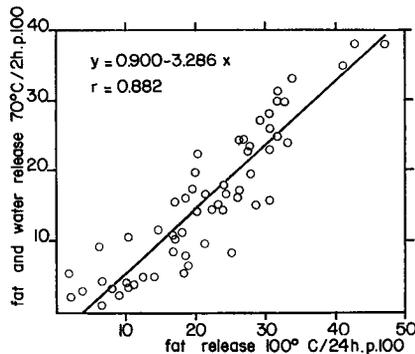


FIG. 3. — Relationship between fat released by liver samples at 100°C/24 h (FR) and liquids released following pasteurization at 70°C/2 h (LR)

The effect of dietary additives on liver composition and FR
(table 3, fig. 4)

This study was conducted on samples removed from 120 livers of geese forced with cooked maize (60) or with pelleted enriched maize (60) (see Materials and Methods). The liver samples were arbitrarily selected from similar weight groups

TABLE 3

Composition and fat release (100°C/24 h) from samples of livers drawn from geese fed cooked maize or pelleted enriched maize (60 samples per diet)

| | Cooked maize | Enriched pelleted maize | SEM ⁺ |
|----------------------------------|--------------|-------------------------|------------------|
| Liver weight (g) | 756 | 764 | 21 |
| Water (p. 100) | 35.4 | 37.3 | 0.5* |
| Total fat (p. 100) | 56.8 | 54.5 | 0.5* |
| Total protein (p. 100) | 7.87 | 8.33 | 0.1* |
| Phosphorus (mg/100 g) | 119 | 128 | 2 |
| Fat release (p. 100) | 23.4 | 21.2 | 0.9 |

⁺ Standard error of the mean.

^{*} Statistically significant difference between the treatments, P < 0.05.

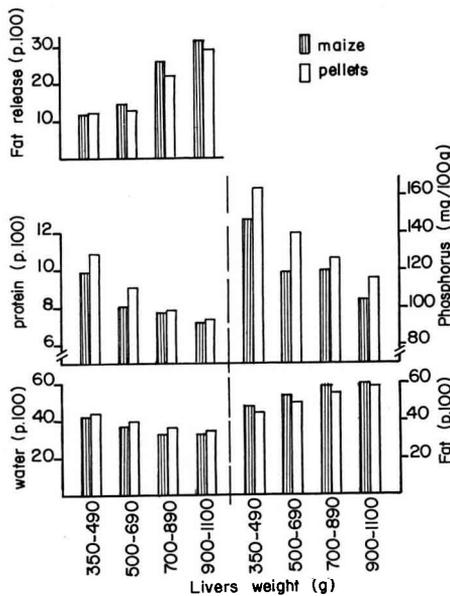


FIG. 4. — Water, protein, fat release (FR) (left), fat and phosphorus (right) of liver samples obtained from fatty livers of geese crammed with cooked maize or with enriched pelleted maize. Barred columns, cooked maize; empty columns, enriched pelleted maize.

of each dietary treatment : < 490 g (10 p. 100 of total number of livers), 500-690 g (16 p. 100), 700-890 g (46 p. 100), > 900 g (28 p. 100). The livers of the geese fed with the pelleted enriched diet contained more protein, phosphorus and moisture but less fat than the ones fed with cooked maize, and their FR was lower (not to a statistically significant degree) (table 3). These changes were valid for the various weight groups (fig. 4). Total fat concentration and FR increased, while total protein, phosphorus and water concentrations decreased with liver size.

The effect of freezing liver samples on FR and LR (fig. 5)

The assays were conducted on 38 liver samples. FR and LR were determined before and following one month's storage at -20°C . Freezing had no effect on LR but increased slightly the FR (not statistically significant). The values before freezing were highly correlated to the ones obtained following freezing.

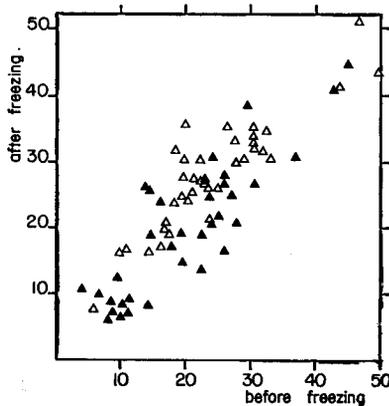


Fig. 5. — Relationship between fresh liver samples and frozen samples (1 month -20°C) drawn from the same liver in the liquids released (LR) and the fat released (FR)

| | |
|--------------------------|--------------------------|
| LR ▲ | FR △ |
| $\bar{x} = 19.5 \pm 1.6$ | $\bar{x} = 23.8 \pm 1.6$ |
| $\bar{y} = 19.8 \pm 1.7$ | $\bar{y} = 27.5 \pm 1.4$ |
| $r = 0.849$ | $r = 0.894$ |

DISCUSSION

The described procedure is suggested as a simple tool for the quantitative determination of liver quality in industry and in research. The significance of fatty liver quality may differ according to the farmer and manufacturer. The farmer is interested in the production of grade A livers of maximal weight ; the manufacturer is interested in grade A big livers which release minimal amounts of fat during heat processing. Although it was shown in the present work that liver weight is significantly correlated to its fat content and FR, the magnitude of the correlation coefficient ($r = 0.41$ and $r = 0.50$ for size *vs.* total fat or FR) was quite low. A higher correlation coefficient was found for total fat *vs.* FR ($r = 0.72$) than for liver weight *vs.* fat or FR, which means that FR depends more on the fat concentration than on the liver size. However, there is a wide individual variation in this character (FR).

The results obtained in the present work, carried out on a large number of geese fatty livers, are in accordance with earlier works (NIR and PEREK, 1971 ; NIR, PEREK and KATZ, 1972 ; BLUM and LECLERCQ, 1973) which stated that fatty liver formation is due essentially to a hypertrophy caused by fat surcharge, the added fat being essentially triglycerides.

According to LABIE and TOURNUT, 1970, a part of the hepatocytes in large fatty livers, especially in the peripheral parts of the lobules, are transformed into an enormous lipidic vesicle. The cytoplasm and pycnotic nucleus are rejected to the periphery. The distended cellular membranes may rupture and the lipidic vesicles of many cells join to form a voluminous mass, the polycyclic outline of which is drawn by the membranes' debris. Repeated experiments made by these workers have shown that livers with ruptured cellular membranes lose large amounts of fat during cooking.

At this stage of our knowledge, a major question arises : to what degree can the fatty livers' composition and « quality » be modified? Different genetic sources had no effect in this respect (see Materials and Methods). It was shown in the present work that dietary additives may affect liver composition and FR. Addition of protein, phosphorus and calcium to the maize diet increased the lean cell mass (moisture, protein and phosphorus) of the liver, which is negatively correlated to FR (table 2). The lean mass of the hepatocytes is probably associated with the strength of the cellular membranes which prevent fat release from the cells. It is suggested that denaturation of the cell membranes by heat or dehydration alter only partly the cell's ability to retain its fat.

The low iodine number found for liver fat is in accordance with the findings of BALDISSERA NORDIO (1971) and of LECLERCQ *et al.* (1968), who reported that fatty acids in the livers of crammed geese are composed essentially of oleic, palmitic and stearic acids. The same is true for palm oil, which has iodine number values quite similar to those found for the fat of goose liver (FIESER and FIESER, 1962).

It may be suggested that the negative correlation found between the iodine number *vs.* total fat and phospholipids (Lipid P) concentrations may derive from a relative decrease in fatty acids desaturation in the highly steatic livers. The lack of relationship between FR and the iodine number shows that within the limits of this study, the degree of fatty acids saturation did not affect the FR.

The fat becomes deposited in the fatty livers without changing substantially the water/protein ratio. In the present work this ratio was about 4.6 : 1. This ratio is close to that found in normal livers. Therefore, it could be suggested that the added triglycerides accumulate in the hepatocyte without profoundly affecting the nature of its protoplasm. This is obvious since such a change would affect the normal functions of the liver and cause the death of the goose. The evolutionary aspect of liver steatosis was discussed by BLUM and LECLERCQ, 1973.

The finding that freezing had only a slight effect on FR and no effect on LR needs further confirmation. The effect of freezing on small samples could be at variance with its effect on whole livers, mainly because the rate of freezing and thawing is much slower for the whole liver than for a sample of it.

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RÉSUMÉ

RELATION ENTRE LA COMPOSITION DU FOIE GRAS D'OIES ET LE DEGRÉ DE STÉATOSE HÉPATIQUE : INFLUENCE DE TRAITEMENTS ALIMENTAIRES ET TECHNIQUES ET MÉTHODE SIMPLE PERMETTANT D'ESTIMER SA QUALITÉ

Une méthode simple permettant d'estimer la qualité du foie gras d'oies est décrite. Cette dernière est basée essentiellement sur la matière grasse dégagée par un échantillon de foie à 100°C/24 h (FR) ou sur les liquides dégagés par l'échantillon durant sa pasteurisation à 70°C/2 h (LR). Il existe une corrélation élevée entre ces procédés ($r = 0.88$). La moyenne de l'FR déterminée sur 227 foies gras était de 19,4 avec un écart-type de ± 0.8 . Le LR atteint environ 75 p. 100 des valeurs obtenues par le procédé FR et est prévisible à partir de l'FR ($y = 0.9x - 3.29$).

La valeur FR est en corrélation positive avec la concentration de matière grasse ($r = 0.72$) et en corrélation négative avec la concentration des protides ($r = 0.61$). L'addition de protéines et de phosphore à l'aliment de gavage augmente leur concentration dans les foies gras et par voie de conséquence diminue la matière grasse et les liquides dégagés durant le chauffage.

La congélation d'échantillons de foie gras durant 1 mois à -20°C n'a pas changé significativement leurs valeurs FR et LR. Le cholestérol et l'indice d'iode ne sont pas liés à l'FR.

Les possibilités et limites de la méthode proposée sont discutées.

RÉFÉRENCES

- AOAC, 1960. *Methods of Analysis*. 9th ed. Association of Official Agricultural Chemists, Washington, D. C.
- BALDISSERA NORDIO C., 1971. Aspetti e possibilità dell' allevamento del palmipedi in Italia con particolare riguardo alla produzione del fegato grasso. *Delli atti delle giornate avicole varesine*, **2**, 121-161.
- BLUM J.-C., LECLERCQ B., 1973. Nouvelles précisions sur les modifications biochimiques et histologiques du foie provoquées par le gavage. *Giornate Avicole Internazionali Varese 31 May*, **2**, 193-207.
- FIESER F., FIESER MARY, 1962. *Advanced Organic Chemistry*. Chapman et Hall, Ltd, London.
- LABIE C., TOURNUT J., 1970. Recherches sur les modifications histologiques et biochimiques chez les oies soumises au gavage. *Cahiers de Médecine vétérinaire*, **39**, 247-261.
- LECLERCQ B., DURAND G., DELPECH P., BLUM J.-C., 1968. Note préliminaire sur l'évolution des constituants biochimiques du foie au cours du gavage de l'oie. *Ann. Biol. anim. Bioch. Biophys.*, **8**, 549-556.
- NIR I., PEREK M., 1971. The effect of various protein levels in feed of goslings during the preparatory period in fatty liver production and blood plasma components. *Ann. Biol. anim. Bioch. Biophys.*, **11**, 645-656.
- NIR I., PEREK M., KATZ, 1972. The influence of soybean meal supplemented to the maize diet of force-fed geese upon their liver, organ and blood plasma components. *Ann. Biol. anim. Bioch. Biophys.*, **12**, 77-89.
- SZYLYT M., LECLERCQ B., IVOREC-SZYLYT O., 1968. Relations spécifiques entre les lactodéhydrogénases du serum et du foie chez l'oie : détermination quantitative et caractérisation électrophorétique. *C. R. Acad. Sc. (Paris)*, **266**, 952-955.