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# Effects of iso-energetic low-fat feed, soybean oil or palm oil containing feed offered to laying hens, either separately or for self-selection, on feed intake, laying and reproductive performance and on egg quality

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# Effects of iso-energetic low-fat feed, soybean oil or palm oil containing feed offered to laying hens, either separately or for self-selection, on feed intake, laying and reproductive performance and on egg quality

Sven Dänicke and Ingrid Halle[1]


## Abstract

An experiment was carried out with Lohmann Brown laying hybrids to examine the effects of feeding a low-fat feed (LF, 12 g crude fat per kg as fed), a feed containing 150 g soybean oil (SO) or 150 g palm oil (PO) per kg as fed, either separately or as a cafeteria feed (choice-fed group, LF/SO/PO), on voluntary feed intake and laying performance, on reproductive performance and on egg quality. All diets were formulated to be iso-energetic.The experiment lasted from week 22 to 50 of age and 15 hens were assigned to each of the 4 treatments.

Hens fed separately the LF-, SO- and PO-feeds consumed 118 g, 121 g and 117 g daily, respectively, whereas LF/SO/PO-fed hens consumed 131 g in total. Hens of the latter group consumed 17 % of the LF-feed, 38 % of the PO-feed and 45 % of the SO-feed on average. Over the whole experiment, hens increased the proportion of intake of the LF-feed from 11 % to 21 % and decreased that of the SO- and PO-feed from 46 % to 43 % and from 43 % to 38 %, respectively, at the same time. LF/SO/PO-fed hens and hens fed the SO-feed had a higher daily egg mass production (61.0 g and 60.5 g) than hens fed the LF- or PO-feed (56.1 g and 57.8 g), due mainly to the differences in egg weight.

Linoleic acid concentration in LF-, SO-, PO- and LF/SO/PO-diet was 2.8, 72.8, 15.8 and 40 g/kg, respectively, and that of linolenic acid was 0.4 , 12.6, 1.8 and 6.4 g/kg. Fatty acid composition of yolks reflected that of the diets in the case of SO- and LF/SO/PO-fed hens whereas a similar fatty acid pattern was observed in yolks from eggs obtained from LF- and PO-fed hens. These changes in the fatty acid profile were not associated with a change in reproductive performance. Similarly, egg quality (breaking strength, proportions of yolk and albumen) was also unaffected.


*Key words: laying hens, dietary fat type, choice feeding*


## Zusammenfassung

**Einflüsse von Futtermischungen mit niedrigem Fettgehalt, mit Sojaöl oder Palmfett, entweder einzeln verfüttert oder zur Selbstauswahl angeboten, auf Futteraufnahme, Legeleistung und Reproduktionsleistung von Legehennen sowie auf Eiqualitätsparameter**

Es wurde ein Fütterungsversuch mit Legehybriden durchgeführt, um die Effekte der Fütterung einer Mischung mit niedrigem Fettgehalt (LF, 12 g Rohfett je kg Originalsubstanz[OS]), mit 150 g Sojaöl (SO) je kg OS sowie 150 g Palmöl (PO) je kg OS auf Futteraufnahme, Legeleistung, Reproduktionsleistung und Eiqualität zu untersuchen, wobei die Mischungen iso-energetisch ausgeglichen waren und entweder einzeln verfüttert oder zur Selbstauswahl (LF/SO/PO) angeboten wurden (15 Hennen/Gruppe). Der Versuch wurde mit der 22. Lebenswoche begonnen und endete mit der 50. Lebenswoche. Die Hennen, denen die Mischungen LF, SO und PO separat gefüttert wurden, verzehrten täglich 118 g, 121 g und 117 g, während die Hennen der LF/SO/PO-Gruppe insgesamt 131 g aufnahmen. Die einzelnen Anteile an der Gesamtaufnahme betrugen bei dieser Gruppe im Mittel 17 % aus der Mischung LF, 45 % aus SO und 38 % aus PO. Im Versuchsverlauf steigerten die Hennen die Aufnahme aus der LF-Mischung von 11 bis 21 % und verringerten gleichzeitig die Aufnahme aus den Mischungen SO und PO von 46 auf 43 % bzw. von 43 auf 38 %. Die Hennen der Gruppen LF/SO/PO sowie SO wiesen eine höhere tägliche Eimasseproduktion auf (61.0 g bzw. 60.5 g) als die Hennen der Gruppen LF und PO (56.1 g bzw. 57.8 g), hauptsächlich aufgrund der Unterschiede in den Einzeleigewichten.

Die Linolsäurekonzentration im LF-, SO-, PO- und LF/SO/PO-Futter betrug 2.8, 72.8, 15.8 und 40.0 g/kg während die entsprechenden Linolensäurekonzentrationen 0.4, 12.6, 1.8 und 6.4 g/kg betrugen. Die Fettsäurekonzentration der Dotter reflektierte die des Futters in den Gruppen SO und LF/SO/PO, während ein annähernd gleiches Fettsäurenmuster in den Dottern der Gruppen LF und PO festgestellt wurde. Die Veränderungen im Fettsäurenprofil wirkten sich nicht auf die Reproduktionsleistung der Hennen aus. Die Eiqualität (Bruchfestigkeit, Dotter- und Eiklaranteil) stellte sich ebenfalls unbeeinflusst dar.


*Schlüsselwörter: Legehenne, Futterfettart, Wahlfütterung*

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## 1 Introduction

Generally, the chemical composition of eggs produced by laying hens is biologically aimed for an optimum nutritional environment for the developing embryo. Therefore, a more or less constant chemical composition of eggs is a precondition for meeting the needs of the embryo. On the other hand, fatty acid composition of egg yolk can be markedly influenced by dietary manipulations (for review see Halle and Jeroch, 1996). Therefore, several studies were carried out to investigate the effects of dietary fatty acid composition, or the level of fatty acids in the diet, on fatty acid composition of egg yolk and on reproductive performance of quail hens (Vilchez et al., 1991) and broiler breeder hens (Halle, 1998) with special consideration of the essentiality of linoleic acid (C18:2 n-6) or linolenic acid (C18:3 n-3). The German Society of Nutritional Physiology recommends to supply laying and breeder hen diets with 10 g of C18:2 n-6 per kg and 1 g of C18:3 n-3 per kg on the basis of the literature and allowing for a safety margin (GfE, 1999). One way to evaluate such recommendations is to offer the hen several diets differing in fatty acid content and fatty acid composition, and to observe its response under choice feeding conditions. It was demonstrated for other nutrients that the broiler and the hen are able to select to meet their requirements, for example, for protein or lysine, when choice feeding is allowed (Forbes and Sharitmadari, 1996; Richter and Hennig, 1986). Therefore, it would be of interest to see if the hen would be able to assemble a diet for itself which meets its requirement for fatty acids which are essential for metabolic purposes, including for an optimized reproductive performance (laying intensity, hatchability) and fatty acid composition of the egg yolk for the embryo.

Hence, the aim of the study was to test a low-fat feed which does not meet the above mentioned recommendations, a feed containing palm acid oil which is rich in the saturated palmitic acid, and a soybean oil containing feed which is abundant in linoleic acid, either alone or as a cafeteria meal, i.e. under choice-feeding conditions.

## 2 Material and methods

### *2.1 Feeds*

Generally, feeds were formulated on a semi-purified basis in order to decrease the dietary fatty acid content below a suggested essential fatty acid requirement on one hand, and to increase the fatty acid contents to high levels on the other hand, while maintaining the energy concentration in all feeds. Clearly, such feed formulation does not reflect a practical situation, but seemed necessary to observe responses in hens.

The low fat feed comprised wheat, soybean meal and maize starch and contained 12 g of crude fat of which was 2.8 g of linoleic acid (28 % of the GfE-recommendations) and 0.4 g linolenic acid (40% of the GfE-recommendations) per kg. The fat substituted feeds were formulated to have a similar ME-concentration to the low-fat feed in order to avoid an ME-mediated control of feed intake. Maize starch was iso-energetically substituted by either 150 g soybean oil or 150 g palm oil per kg and variable proportions of cellulose and quartz sand (Table 1). In all these feeds, not only crude protein concentration could be kept constant but also the protein quality was maintained. Fatty acid contents of the feeds and of soybean oil and palm oil are shown in Tables 1 and 2, respectively.

### *2.2 Performance experiment*

A total of 60 laying hybrids of the Lohmann Brown strain were used in the experiment. Fifteen hens were assigned to each of the 4 treatments: low-fat, 150 g palm oil per kg, 150 g soybean oil per kg and cafeteria offering of the 3 fat type feeds (choice feeding). Hens were placed into a 3-floor-cage battery. Each hen was kept in a cage which had a front width of 40 cm and a depth of 50 cm. Water was constantly provided by nipple drinkers. Trough width corresponded to the front width of the cages for the groups fed the low fat, palm fat and soybean oil feed separately whereas three plastic boxes of 10 cm width were placed in each trough of the cages where the choice-fed hens were kept.

Experiment started at week 22 of age after a pre-experimental period of 2 weeks where the hens were fed a commercial diet. The study lasted 28 weeks. Hens were weighed at the beginning (mean body weight of the flock: 1875 g ± 135 g) and at the end of the experiment. The number of eggs laid was recorded daily and 2 eggs per hen and week were weighed to determine the mean egg weight. Feed was offered for ad libitum consumption and was weighed back weekly.

### *2.3 Reproductive performance*

All hens of the performance experiment were artificially inseminated using a mixed sperm beginning from week 35 of age. Ten eggs of each hen were collected and hatched. The number of fertilized eggs, hatched chicks and chicks not able to complete hatching were recorded.

### *2.4 Egg quality parameters*

Four eggs from each hen were collected at weeks 34 and 43 of age. Egg quality parameters were determined at week 34 of age only. Egg weight, weight of shell including inner shell membrane and weight of yolk were recorded for 2 eggs. Weight of albumen was calculated by difference. Breaking strength was determined for the other 2 eggs. Yolk colour was estimated by using a Roche-fan

Table 1
Composition of experimental feeds (g/kg)

| | Feed type | | |
|---|---|---|---|
| | Low fat | Soybean oil | Palm oil |
| Wheat (121 g CP/kg) | 168 | 168 | 168 |
| Soybean meal (440 g CP/kg) | 330 | 330 | 330 |
| DL-Methionine | 3 | 3 | 3 |
| Soybean oil | - | 150 | - |
| Palm oil | - | - | 150 |
| Maize starch | 380 | - | 70 |
| Cellulose | - | 40 | 40 |
| Quartz sand | - | 190 | 120 |
| Calciumcarbonate | 80 | 80 | 80 |
| Di-calciumphosphate | 25 | 25 | 25 |
| Sodium chloride | 4 | 4 | 4 |
| Premix[1] | 10 | 10 | 10 |
| *Calculated composition:* | | | |
| Crude protein[2] | 163 | 163 | 163 |
| Methionine | 5.3 | 5.3 | 5.3 |
| Methionine+Cystine | 7.7 | 7.7 | 7.7 |
| $AME_N$ (MJ/kg) | 10.83 | 10.83 | 10.83 |
| Calcium | 37.1 | 37.1 | 37.1 |
| Total phosphorus | 7.4 | 7.4 | 7.4 |
| Sodium | 1.6 | 1.6 | 1.6 |
| *Analyzed composition (n=2):* | | | |
| Crude protein | 164.5 | 163.2 | 165.2 |
| Crude fat | 12.1 | 154.8 | 159.1 |
| Palmitic acid (C16:0) | 0.8 | 13.8 | 66.7 |
| Stearic acid (C18:0) | 0.2 | 4.2 | 12.1 |
| Oleic acid (C18:1) | 1.4 | 41.2 | 56.0 |
| Linoleic acid (C18:2, n-6) | 2.8 | 72.8 | 15.8 |
| Linolenic acid (C18:3, n-3) | 0.4 | 12.6 | 1.8 |

Abbreviations: $AME_N$ - apparent metabolizable energy content corrected for zero N-balance

[1] Provided per kg feed: Fe, 25 mg; Cu, 5 mg; Zn, 75 mg; Mn, 60 mg; Se, 0.1 mg; I, 0.5 mg; Co, 0.1 mg; vitamin A, 3 mg; vitamin $D_3$, 50 µg; vitamin E, 20 mg; vitamin K, 2.5 mg, vitamin $B_1$, 1 mg; vitamin $B_2$, 4 mg; vitamin $B_6$, 3 mg; vitamin $B_{12}$, 10 µg; pantothenic acid, 10 mg; nicotinic acid, 25 mg; biotin, 102 µg; folic acid, 0.75 mg; choline chloride, 400 mg; BHT, 120 mg

[2] Based on analysis of the protein premix (Wheat and soya bean meal) and consideration of amino acid supplements

Table 2
Main fatty acids in soybean oil and palm oil (g/kg, n=2)

| | Soybean oil | Palm oil |
|---|---|---|
| Palmitic acid (C16:0) | 86.7 | 444.0 |
| Stearic acid (C18:0) | 34.2 | 80.0 |
| Oleic acid (C18:1) | 251.1 | 358.0 |
| Linoleic acid (C18:2, n-6) | 452.3 | 76.0 |
| Linolenic acid (C18:3, n-3) | 72.1 | 1.0 |

(15 fans, F. Hoffmann-La Roche Ltd., Basel, Switzerland). Egg yolks were homogenized from the eggs laid at weeks 34 and 43 of age and then frozen for subsequent analysis of fatty acids.

*2.5 Analysis*

Crude fat and crude protein of the feeds were analyzed according to the methods of the VDLUFA (Naumann and Bassler, 1993). Crude fat of feeds and egg yolks were extracted with chloroform-methanol following acidification with 6 N HCl (excepting the yolk samples). Fatty acids of the fat extracts were methylated with trimethylsulfoniumhydroxide and the resulting methyl esters were identified from their retention time using a gas chromatography system, which consists of the HP 5890 gas-chromatograph, the HP 7673 autosampler and the HP 3365 data-station. The FFAP-fused silica column used for separation had a length of 30 m and an inner diameter of 0.53 mm. Helium was used as the carrier gas with a flow

Table 3
Performance of laying hens offered a low-fat feed, a feed containing 15% soybean oil or a diet containing 15 % palm oil (n=15) either separately or for self-selection(choice feeding) from 22. to 50. week of age

| Feed | Daily feed intake (g/hen) | Daily egg mass (g/hen) | Egg weight (g/egg) | Laying intensity (%) | Feed conversion (g/g egg mass) |
|---|---|---|---|---|---|
| Low fat (LF) | 117.0 | 56.1 | 62.9 | 89.2 | 2.14 |
| 15 % soybean oil (S) | 121.2 | 60.2 | 69.5 | 87.1 | 2.04 |
| 15 % palm oil (P) | 117.1 | 57.8 | 66.4 | 87.3 | 2.05 |
| Choice feeding (LF/S/P) | 130.9 | 61.0 | 68.6 | 88.8 | 2.19 |
| *ANOVA (Probability)* | | | | | |
| Feed | 0.021 | 0.017 | <0.001 | 0.802 | 0.282 |
| Laying month | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Feed x laying month | <0.001 | 0.162 | 0.592 | 0.274 | <0.001 |
| Pooled SEM[1] | 6.6 | 2.6 | 2.2 | 2.8 | 0.1 |

[1] Pooled standard error of means

of 9 ml/min. A flame ionisation detector was used for detection of the fatty acids.

*2.6 Statistics*

Performance data and fatty acid composition of egg yolks were tested by a two way factorial design of ANOVA with repeated measurements:

$$y_{ijk} = \mu + a_i + b_j + (axb)_{ij} + ck_{(axb)} + e_{ijk}$$

where $y_{ijk}$ = tested parameter of a hen k fed a feed type i at laying month j, μ = overall mean, $a_i$ (fixed effect) = feed type (low-fat, palm acid oil, soybean oil, cafeteria), $b_j$ (fixed effect) = laying month (1 to 7), $(axb)_{ij}$ = interactions between feed type and laying month, $ck_{(axb)}$ (random effect) = effect of repeated measurements (different laying months) within the same hen k, i.e., variance component contributed by the hens, $e_{ijk}$ = error term.

Mean value differences were evaluated by the Tukey-test.

Furthermore, the variance in intake of the 3 particular feeds by choice fed hens was evaluated by the following model:

$$y_{ijk} = \mu + a_i + b_{j(i)} + b^2_{j(i)} + ck_{(axb)} + e_{ijk}$$

where $y_{ijk}$ = feed intake of a hen k offered a feed type i at laying month j, μ = overall mean, ai (fixed effect) = feed type (low-fat, palm acid oil, soybean oil, cafeteria), $b_j$ (fixed effect) = laying month, linear effect (1 to 7), $b^2_j$ (fixed effect) = laying month, quadratic effect (1 to 7), $c_{k(axb)}$ (random effect) = effect of repeated measurements (different laying months) within the same hen k, i.e., variance component contributed by the hens, $e_{ijk}$ = error term.

Differences in mean values were evaluated for significance by t-test for dependent variables.

Other parameters were evaluated by one-way-ANOVA with feed type being the independent variable.

$$y_{ij} = \ + a_i + e_{ij}$$

where $y_{ij}$ = tested parameter of a hen j fed a feed type i, $a_i$ (fixed effect) = feed type (low-fat, palm acid oil, soybean oil, cafeteria), $e_{ij}$ = error term.

Statistics were carried out using the Statistica for the Windows™ (STATSOFT Inc., 1994) operating system and the SAS-software (SAS Institute, 1985).

**Results**

No hen died during the experiment. Performance parameters for the whole experiment and for the particular laying months are summarized in Table 3. If all laying months are viewed together, then the laying intensity was not influenced by any of the treatments, whereas feed intake, egg weight and egg mass were significantly affected by the feed type. Choice fed hens consumed significantly more feed then hens fed the low-fat or palm oil feed alone (Figures 1 and 2). Egg weight from hens fed the low-fat feed was significantly lower than that of all other groups (Figure 3). The heaviest eggs were laid by choice fed hens and by soybean oil fed hens. Daily egg mass production was highest in choice fed hens, which was significantly different from the egg mass produced by hens fed the low-fat or palm oil feed. Feed conversion ratio was not influenced by feed type.

Significant interactions between feed type and laying months were detected for feed conversion and feed intake which indicates that the course of feed intake during the

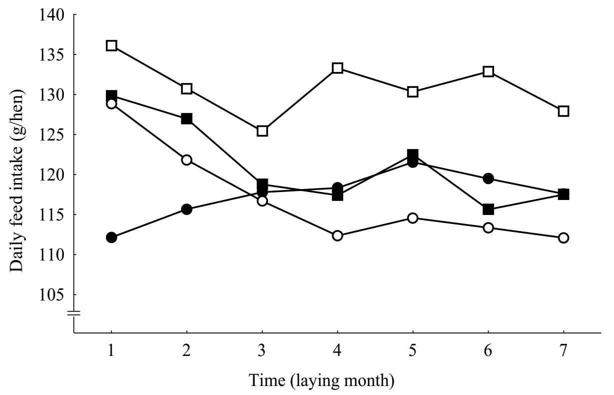


Fig. 1
Effect of offering laying hens a low-fat feed, a feed containing 15 % soybean oil or a feed containing 15 % palm oil either separately or for self-selection(choice feeding) on feed intake (n=15)
(Choice feeding, —□— , low fat, —●— , 15 % soybean oil, —■— , 15 % palm oil, —○— )

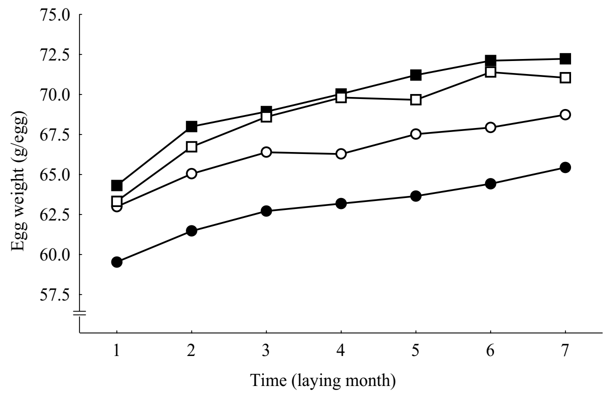


Fig. 3
Effect of offering laying hens a low-fat feed, a feed containing 15% soybean oil or a feed containing 15 % palm oil either separately or for self-selection(choice feeding) on egg weight (n=15)
(Choice feeding, —□— , low fat, —●— , 15 % soybean oil, —■— , 15 % palm oil, —○— )

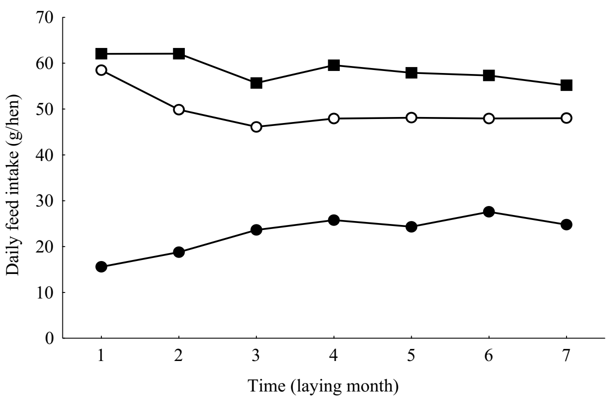


Fig. 2
Effect of choice feeding on intake of a low fat feed, a feed containing 15 % soybean oil or 15 % palm oil (n=15)
( low fat, —●— , 15 % soybean oil, —■— , 15 % palm oil, —○— )

experiment was affected by the feed in a different manner (Figure 1). Whereas the feed intake of choice fed hens remained at a high level over the whole experiment, hens offered the low-fat feed alone increased their feed intake and hens fed the feeds containing fat decreased intake at the same time.

A separate evaluation of the feed amount drawn from the 3 feed types by the choice fed hens is given in Table 4. Generally, it becomes clear that hens preferred the soybean oil feed over the palm oil feed and over the low-fat feed. Mean values were significantly different for each comparison. Choice fed hens increased the intake of the low-fat feed (linear effect: p=0.011) and decreased the intake of the palm oil feed (quadratic effect: p=0.007) at the same time during the first three months of the experiment whereas the soybean oil feed was consumed at relatively constant proportions over the whole experiment (Figure 2).

Only the hens of the low-fat group gained significantly less live weight than those of the other groups (Figure 4).

Reproductive performance of the hens was not significantly influenced by feed type (Table 5). Beside the already described feed effect on egg weight, only the yolk colour was affected by the feed, whereas all other egg quality parameters appeared unaffected by dietary treatments (Table 6). Because feeds were not supplemented with carotinoides the yolks of the hens fed the low-fat feed were nearly colourless. Also, 150 g of palm oil per kg feed did not contribute to yolk colour whereas soybean oil substitution resulted in a certain degree of yolk colour. The

Table 4
Mean intake of low fat, soybean oil and palm oil feed of choice fed hens (g per hen and day, n=15, 22.-50. week of age)

| | Low fat (LF) | 15 % soybean oil (SO) | 15 % palm oil (PO) | Pooled SEM[1] |
|---|---|---|---|---|
| Mean intake[2] | 22.9[a] | 58.5[c] | 49.5[b] | 1.8 |
| *ANOVA (probability)* | | | | |
| Laying month (linear) | 0.011 | 0.454 | 0.001 | |
| Laying month (quadratic) | 0.064 | 0.760 | 0.007 | |

1 Pooled standard error of means
2 Mean value differences were evaluated by t-test for dependent variables (p<0.05)
a-c-values with no common superscript are significantly different (p<0.05)

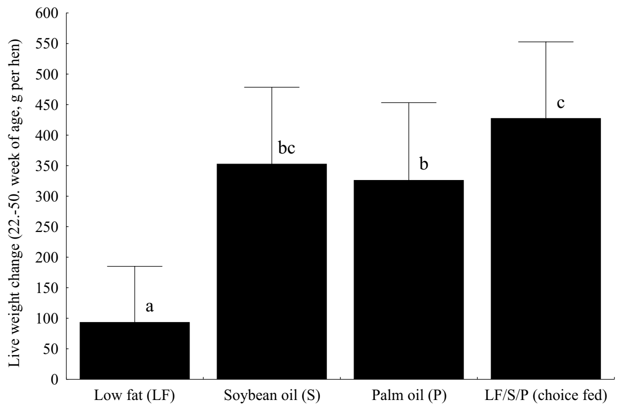


Fig. 4
Effect of offering laying hens a low-fat feed, a feed containing 15 % soybean oil or a feed containing 15 % palm oil either separately or for self-selection(choice feeding) on live weight change from 22.-50. week of age (n=15)
a-c = mean values with no common superscripts are significantly different ($p<0.05$)

yolk colour of the eggs laid by the choice fed hens was lower than that from the soybean oil group and higher than that from the low-fat or palm oil groups.

Fatty acid composition of egg yolks is given in Table 7. All analyzed fatty acids were significantly affected by feed type. An age effect was observed only for stearic acid. Generally, fatty acid composition of egg yolks from the palm oil and soybean oil groups reflected that of the dietary fat types. The fatty acid composition of egg yolks of the choice fed hens was found to be somewhere between that of the yolks from the palm oil and soybean oil groups. Main fatty acids in the yolks of hens fed the low-fat feed were palmitic and oleic acid.

## Discussion

Adaptation in feed intake was observed both in hens fed all three feeds separately and in choice fed hens in the course of the experiment. Differences in feed density seemed to be a factor determining feed intake at the beginning of the experiment when no choice feeding was allowed. Intake of the low-fat feed was increased in the course of the experiment, whereas a decrease occurred in intake of the feeds containing fat (Figure 1) which could be caused by differences in feed density. The density of the feeds could not be kept constant by such an extreme feed formulation as applied in the present experiment. High content of starch in the low-fat feed on one hand, and high fat- and quartz sand contents in the fat containing feeds on the other hand, resulted in differences in feed density. Consequently, the weight per volume was lowest in the low-fat feed, followed by the palm- and soybean oil feeds. The consequence could be that a higher volume of the low-density low-fat feed would have had to be consumed for intake of a similar nutrient quantity and ME compared to the higher-dense fat feeds. Therefore, the hen could be restricted to some extent by its gut capacity at least in the first 3 months of the experiment. During this period, the hens fed the low-fat feed increased their intake to the level of the hens fed the palm oil and soybean oil feed, whereas the latter decreased their intake at the same time. Both the increase in feed intake of the low-fat group and the simultaneous decrease in feed intake of hens fed the high-fat feeds could therefore indicate an adaptation to the low energy and high dense energy feeds, when expressed per unit of volume, respectively. Feed intake was nearly similar in all 3 groups after this adaptation period which indicates that the iso-energetic calculated feeds had indeed the same ME-concentration when expressed on a weight basis (see Figure 1). However, this mechanism of adaptation to differences in the ME to volume ratio can not be the only mechanism in regulation of voluntary feed intake, since choice fed hens consumed considerably more feed than all other groups. It is interesting that choice fed hens also increased the intake of the low-fat feed and decreased that of the palm oil feed during the first 3 months of the experiment instead of a completely avoiding of one of the three feeds. After these 3 months, the proportion eaten from these three feeds remained nearly the same over the remainder of the experiment (Figure 2). Although the significantly increased total amount of feed intake compared to the intake of the other groups can not be completely explained by performance, it is very clear that soybean oil feed was preferred to palm oil or low fat feed. In fact, daily egg mass and body weight gain were higher in choice fed hens but a certain degree of feed wastage can not completely ruled out.

It is interesting to note that choice fed hens consumed significantly higher amounts of the soybean oil feed which also gave the best performance when given alone compared to low-fat or palm oil fed hens, which could indicate a fat type or fatty acid composition related effect on performance. There are several indications that ingestion of fat containing feeds modulates gastro-intestinal motility via changes in the release of gastrointestinal neurotransmitters or hormones. An altered gut motility could therefore have an impact on voluntary feed intake. It was demonstrated by Degolier et al. (1997) that neurotensin decreases the frequency and the strength of gizzard and small intestine movement in broilers. The authors reported that neurotensin was released into the hepatic-portal circulation in response to the presence of oleic acid in the duodenum. Moreover, different fat types modulate the release of neurotensin and substance P in a different manner as found by Sagher et al. (1991) in a rat experiment using corn oil, olive oil or butterfat as fat supplements.

The practical consequences of such hormonal changes on regulation of feed intake were demonstrated by Mateos and Sell (1981) who examined the effects of feeding of

Table 5
Reproductive performance of laying hens offered a low-fat feed, a feed containing 15% soybean oil or a feed containing 15 % palm oil either separately or for self-selection (choice feeding) (150 eggs per group were hatched)

| Diet | Eggs fertilized | Chicks not able to hatch | Dead chicks | Chicks hatched | |
|---|---|---|---|---|---|
| | (%) | (% of fertilized eggs) | (% of fertilized eggs) | (% ) | (% of fertilized eggs) |
| Low fat (LF) | 95.8 | 6.7 | 0.6 | 89.5 | 93.4 |
| 15 % soybean oil (SO) | 89.3 | 9.9 | 1.6 | 79.9 | 88.6 |
| 15 % palm oil (PO) | 93.2 | 2.4 | 2.3 | 88.9 | 95.3 |
| Choice feeding (LF/SO/PO) | 94.9 | 8.5 | 0.7 | 86.0 | 90.7 |
| ANOVA (probability) | 0.412 | 0.156 | 0.563 | 0.240 | 0.239 |
| Pooled SEM[1] | 2.9 | 2.4 | 0.9 | 3.6 | 2.4 |

[1] Pooled standard error of means

Table 6
Quality of eggs laid by hens offered a low-fat feed, a feed containing 15% soybean oil or a feed containing 15 % palm oil either separately or for self-selection (choice feeding)( n=60)

| | Egg weight (g) | Yolk (%) | Shell (%) | Albumen (%) | Yolk color (Roche fan) | Breaking strength (kp) |
|---|---|---|---|---|---|---|
| Low fat (LF) | $62.0^{a}$ | 24.6 | 10.5 | 64.9 | $0.0^{a}$ | 3.93 |
| 15 % soybean oil (SO) | $69.0^{b}$ | 24.1 | 10.2 | 65.7 | $2.5^{c}$ | 4.33 |
| 15 % palm oil (PO) | $64.7^{ab}$ | 24.4 | 10.2 | 65.3 | $0.0^{a}$ | 4.23 |
| Choice feeding (LF/SO/PO) | $66.9^{b}$ | 24.0 | 10.3 | 65.7 | $1.0^{b}$ | 3.66 |
| ANOVA (probability) | 0.002 | 0.784 | 0.856 | 0.684 | <0.001 | 0.123 |
| Pooled SEM[1] | 1.3 | 0.5 | 0.2 | 0.5 | 0.1 | 0.2 |

[1] Pooled standard error of means, $^{a-c}$-values with no common superscript differ significantly within columns (p<0.05)

Table 7
Fatty acid composition of eggs laid by hens offered a low-fat feed, a feed containing 15% soybean oil or a feed containing 15 % palm oil either separately or for self-selection (choice feeding)(n=15)

| Diet | Palmitic acid (C16:0) | Palmit-oleic acid (C16:1) | Stearic acid (C18:0) | Oleic acid (C18:1) | Linoleic acid (C18:2, n-6) | Linolenic acid (C18:3, n-3) | Arachi-donic acid (C20:4, n-6) | Docosa-hexaenic acid (C22:6, n-3) |
|---|---|---|---|---|---|---|---|---|
| Low fat (LF) | $23.8^{c}$ | $5.4^{b}$ | $6.5^{ab}$ | $44.1^{c}$ | $7.4^{a}$ | $0.4^{a}$ | $0.7^{a}$ | $0.5^{b}$ |
| 15 % soybean oil (SO) | $17.8^{a}$ | $1.1^{a}$ | $6.7^{b}$ | $30.5^{a}$ | $29.0^{c}$ | $2.2^{c}$ | $1.3^{b}$ | $0.8^{c}$ |
| 15 % palm oil (PO) | $23.4^{c}$ | $1.6^{a}$ | $6.0^{a}$ | $47.8^{d}$ | $9.1^{a}$ | $0.2^{a}$ | $0.8^{a}$ | $0.3^{a}$ |
| Choice feeding (LF/SO/PO) | $20.6^{b}$ | $1.2^{a}$ | $6.9^{b}$ | $37.5^{b}$ | $20.9^{b}$ | $1.2^{b}$ | $0.8^{a}$ | $0.8^{c}$ |
| *ANOVA (probability)* | | | | | | | | |
| Diet | <0.001 | <0.001 | 0.005 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Week | 0.484 | 0.816 | 0.001 | 0.974 | 0.602 | 0.419 | 0.612 | 0.791 |
| Diet x week | 0.882 | 0.527 | 0.223 | 0.437 | 0.381 | 0.262 | 0.453 | 0.412 |
| Pooled SEM[1] | 0.6 | 0.4 | 0.2 | 1.3 | 1.8 | 0.2 | 0.2 | 0.1 |

[1] Pooled standard error of means
$^{a-d}$-values with no common superscript differ significantly within columns (p<0.05)

different low-fat feeds in the absence or presence of yellow grease (70 g/kg) on the first appearance of an indigestible marker in the excreta of laying hens. This appearance, and consequently the transit time of ingesta through the digestive tract, was delayed when starch was used instead of sucrose and when fat was supplemented to both low-fat feeds, although this effect was more pronounced in the sucrose-based low-fat feed. In a further experiment, Mateos et al. (1982) reported a dose-response related delay in marker appearance when yellow grease proportion was successively increased up to 300 g/kg. These results would indicate that high-fat feeds would consequently decrease feed intake. Such an effect was not observed in the present study. Even under these long-term feeding conditions the soybean oil containing feed was consistently preferred over the other feeds.

Besides the factors discussed which regulate the feed intake of the hen, one aim of the present study was to examine whether or not the hen is able to select a diet which ensures an optimum essential fatty acid supply for embryonic development. It was shown by Vilchez et al. (1990a, b, 1991) that supplementation of diets for Japanese quail hens with palmitic acid or oleic acid decreased embryonic mortality when compared with linoleic or linolenic acid supplements. Moreover, Dänicke et al. (2000) found the percentage of chicks that were unable to complete hatching to be significantly increased when the laying hen diet contained 140 g/kg soybean oil compared to a low fat diet. On the other hand, Halle (1998, 1999a) did not find detrimental effects on reproductive performance of broiler breeder hens up to a dietary fat supplement of 50 g/kg either from palm oil or from safflower oil. Reproductive performance was not influenced by either of the dietary treatments of the present experiment in spite of the extreme feed formulations (low fat or 150 g soybean oil or 150 g palm oil per kg). Also, choice feeding did not improve reproductive performance. Lin et al. (1991) followed the carry over of n-3 and n-6 fatty acids from the yolk to the developing embryo and concluded that the embryonic requirement for n-3 and n-6 fatty acids ranges between 0.4 % and 1.1 % and between 4.8 % and 6.2 % of the egg energy, respectively. Applying these figures to the present data (Tables 3 and 7) and assuming an energy content of 6.5 kJ/g egg and of 39 kJ/g fatty acid, it can be calculated that the requirement for n-3 fatty acids was met between approximately 130-50 %, 440-160 %, 70-30 % and 300-110 % for the groups fed the low fat feed, the feed containing 150 g soybean oil per kg, 150 g palm oil per kg or the choice fed group, respectively. The respective values for the n-6 fatty acids are 100-77 %, 379-293 %, 123-95 % and 271-210 %, respectively. Therefore, it would appear that a marginal deficiency could have occurred for the hens fed the low-fat feed or the palm oil containing feed. However, if there was a deficiency it could not be detected by the parameters investigated.

The fatty acid pattern of egg yolk from eggs obtained from the SO-fed group clearly reflected that of the soybean oil which agrees with observations by Dänicke et al. (2000) who reported a dose-response related non-linear increase in linoleic and linolenic acid when soybean oil contents of the diets were successively increased from 0 to 140 g/kg. Comparable fatty acid composition of yolks from hens fed the LF- and PO-feeds was ascertained in spite of an approximately 150 g/kg difference in dietary fat content. The main fatty acid in palm oil is palmitic acid which is also the main end product of the de-novo fatty acid synthesis. Therefore, mainly palmitic acid, palmitoleic acid, stearic acid and oleic acid in the yolk of the LF-fed hens resulted from the de-novo synthesis of palmitic acid and from elongation and desaturation whereas the latter metabolic conversions in PO-fed hens were mainly based on nutritive supplied palmitic acid. Moreover, LF-fed hens gained significantly less weight and consequently had less body fat than PO-fed hens, which suggests that the newly synthesized fatty acids in LF-hens were mainly directed to the egg rather than to the body stores. Linoleic acid and linolenic acid in yolks of these groups originated either from the low dietary contents or from body reserves built up during the rearing period. The positive relationship between the supply of essential fatty acids and egg weight are well documented (Whitehead, 1981; Whitehead et al., 1991, 1993; Halle, 1996; 1999b; Dänicke et al., 2000) and was also confirmed by the present results.

Calculated linoleic and linolenic acid contents of the diet self-selected by the hens (choice fed group) exceeded the GfE-recommendations approximately fourfold and sixfold, respectively. The linoleic acid content of the self-selected diet decreased during the 28-weeks lasting experiment from approximately 40 to 38 g/kg and that of linolenic acid from 6.7 to 6 g/kg. It should be considered in interpreting fatty acid effects on reproductive performance that an assignment of an observed effect to a particular fatty acid is difficult because of its presence in a mixture of several fatty acids.

Although there were some signs of adaptation, it should be stressed that choice-fed hens consumed feed and fat largely in excess, which was not only converted to the numerically highest daily egg mass production but also to the highest live weight gain or fat deposition, respectively, and presumably due to an increased feed wastage.

Taken together, it can be concluded that the laying hen prefers a soybean oil containing feed over a palm oil containing feed, which in turn was preferred over a low-fat feed when all 3 feeds were offered to the hen at the same time. However, hens of this choice-fed group tended to consume in total more feed than hens fed the 3 feeds separately.

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