Effect of Deoiled Jojoba Meal on Feed Intake in Chickens: Satiating or Taste Effect?

Sabien Vermaut,*,† Kirsten De Coninck,† Gerda Flo,‡ Marnix Cokelaere,‡ Mohammed Onagbesan,† and Eddy Decuypere†

Laboratory of Physiology and Immunology of Domestic Animals, Department of Animal Production, Katholieke Universiteit Leuven, Kardinaal Mercierlaan 92, B-3001 Heverlee, Belgium, and Interdisciplinary Research Center, Katholieke Universiteit Leuven Campus Kortrijk, B-8500 Kortrijk, Belgium

Jojoba is an oilseed shrub of the desert. Deoiled jojoba meal represents a potential ingredient for animal feed due to its high protein content. However, a jojoba-rich diet decreases feed intake. This study aimed to discriminate between satiation and palatability effects of jojoba meal in chickens. In a first experiment, broilers did not freely prefer jojoba meal-supplemented feed when they had another choice. A second experiment was based on a model that could differentiate satiety from palatability effects. A satiety factor inhibited feed intake to a lesser degree in fasted than in nonfasted chickens, whereas the reduction in feed intake due to an unpalatable tasting agent was less affected by hunger. When feed was supplemented with jojoba meal, the reduction in feed intake did not differ between fasted and nonfasted chickens. In conclusion, jojoba meal reduces feed intake in chickens by its taste rather than by inducing satiation.

Keywords: *Jojoba; chickens; feed restriction; taste; satiation*

INTRODUCTION

The jojoba plant (*Simmondsia chinensis*) is a native oilseed shrub of the Sonoran Desert, including parts of Arizona, California, and Mexico. The principal product extracted from the seeds is a liquid wax with characteristics similar to sperm whale oil (Verbiscar and Banigan, 1978). Jojoba oil is used as an additive in mineral oils and cosmetics (Bagby, 1988). Deoiled jojoba meal represents a potential ingredient for animal feed, due to its high protein content (30%). However, supplementing feed with deoiled jojoba meal reduces feed intake in rats (Booth *et al*., 1974; Cokelaere *et al*., 1993), chickens (Ngou Ngoupayou *et al*., 1982; Arnouts *et al*., 1993; Vermaut *et al.*, 1996, 1997), ewes (Manos *et al*., 1986), and rodents (Sherbrooke *et al*., 1976; Ngou Ngoupayou *et al*., 1985). In rats, this effect is mainly caused by simmondsin, simmondsin 2′-ferulate, and related cyanomethylene glycosides (Elliger *et al*., 1974; Cokelaere *et al*., 1992). The working mechanism of pure simmondsin is still unknown, but this feed intake-reducing effect in rats can be abolished by a peripheral cholecystokinin antagonist, suggesting the involvement of cholecystokinin (CCK) (Cokelaere *et al*., 1995a). In contrast with rats, pure simmondsin seems to have no anorexic effect in chickens (Vermaut *et al*., 1996), although complete jojoba meal reduces feed intake in a dose dependent way (Arnouts *et al*., 1993). Apparently, the effect of jojoba meal components on feed intake is different in chickens than in rats.

Therefore, two experiments were aimed at discriminating between satiation (satisfaction in terms of hunger) and palatability (tastefulness) effects of deoiled jojoba meal in chickens. In a first experiment, broilers were offered the choice between a jojoba-rich and a commercial diet. A second experiment was based on a model, constructed by Billington *et al.* (1983), that could differentiate satiety from other nonspecific effects. A satiety factor, such as CCK, should inhibit the feed intake to a lesser degree in fasted hungry chickens than in nonfasted satiated chickens, whereas the effect of aversive and/or unpalatable tasting agents, such as quinine HCl, should be unaffected by the state of hunger (Gibbs *et al.*, 1973; Bartness and Waldbillig, 1984). Based on this model, the effect of fasting on the feed intake-reducing activity of deoiled jojoba meal was investigated and compared to the effects of quinine HCl and CCK. If the deoiled jojoba meal, like CCK, causes satiety, feed intake will be less reduced in fasted chickens than in nonfasted chickens, while no interaction between the feeding status and jojoba meal treatment is expected if jojoba meal, like quinine HCl, causes taste aversion.

EXPERIMENTAL PROCEDURES

Materials. Jojoba nuts (Jojoba Israel, Kibbutz Hatzerim, Negev, Israel) containing 50% jojoba oil, were pressed in Israel at a temperature of 50 °C. These imported jojoba press-cakes, still containing 13.6 ± 0.5% fat, were deoiled by Soxhlet extraction for 8 h with *n*-hexane. After extraction the fat content was 1.3 ± 0.3%, as measured by Soxhlet (1 h extraction with petroleum ether). Cholecystokinin octapeptide (CCK-8) was purchased from Sigma, St. Louis, MO.

Animals, Housing, and Management. *Group 1 Animals.* One hundred 1-day old female broiler chicks (Hybro) were obtained from a local hatchery (Euribrid, Aarschot, Belgium) and raised in floor pens. During the first 3 weeks all chicks had free access to a commercial broiler diet (Hendrix, Belgium; crude protein 21%, metabolizable energy 12.5 MJ/kg). At the age of 3 weeks, they were divided into four groups of 25 chickens each. The initial mean body weight of these groups did not differ. Access to water was unrestricted. Temperature was set at 32 °C during the first week, set at 28 °C during the second week, and then gradually decreased by 2 °C/week until 22 °C was reached. Light schedule was set according to current practices for broilers (23 light−1 dark).

* Author to whom correspondence should be addressed (fax, ++32 16 32 19 94; e-mail, sabien.vermaut@agr.kuleuven.ac.be).

† Department of Animal Production.

‡ Interdisciplinary Research Center.

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Group 2 Animals. Fifty-six 1-day old female broiler chicks (Hybro, Euribrid) were raised in a floor pen for 3 weeks. During this period all chickens were provided ad libitum with a commercial broiler diet. At the age of 3 weeks, they were divided into 14 groups of four chickens each. All chickens were individually housed in cages. The initial mean body weight of these groups did not differ. Again, the birds had free access to water and the commercial diet, presented in special feeders to avoid spilling of the feed. Temperature and light schedule were set according to current practices for broilers (cf. group 1).

Experimental Design. *Experiment 1.* For this experiment, the chickens of group 1 were used. At the age of 3 weeks two groups were given the choice between a commercial diet in one feeder and a jojoba-rich diet (commercial diet mixed with 8% deoiled Israeli jojoba meal) in another feeder (JO-C). The other two groups of birds were provided access to two feeders both filled with the commercial diet (control group) (C-C). All groups had free access to feed. Feeders were moved daily to avoid habituation or learning during 3 weeks. Daily feed uptake from each feeder was measured. Chickens were observed repeatedly during the first 15 min after changing the location of the feeders.

Experiment 2. For this experiment, the animals of group 2 were used. In the first part of this experiment, the birds were previously deprived of feed for 2 h (0800−1000) to synchronize the start of feed intake (nonfasted group). Each group of four chickens was fed one of the following diets: (a) control feed 15 min after an intraperitoneal injection (ip) of CCK-8 (5, 10, 20, or 40 μg/kg of body weight, respectively) (CCK), (b) feed supplemented with increasing concentrations (0.1%, 0.25%, 0.5%, or 1.0%, respectively) of the unpalatable tasting quinine HCl (QHCl), (c) feed supplemented with increasing concentrations (4%, 8%, 12%, or 16%, respectively) of deoiled jojoba meal (JO), (d) control diet 15 min after an ip injection of saline (Cip) (aimed as a control for CCK), and (e) control diet without previous saline injection (C) (aimed as a control for JO and QHCl). Feed intake was measured 30 and 60 min after feed presentation. After 60 min all chickens received the commercial diet ad libitum, and feed intake was recorded after 30 min.

In the second part of the experiment, the same experimental setup was repeated but now the same chickens were fasted for 24 h (1000−1000) (fasted group).

Feed intake was always expressed as a percentage of the average control feed intake (C + Cip) of the same testing day. The average control feed intake was calculated as a mean of both C and Cip because no statistically significant difference was seen between these two control groups. Moreover, in this way, feed intakes of QHCl, JO, and CCK, expressed as a percentage of the same average control feed intake, are more comparable. Between two testing days, a minimum resting period of 22 h with an ad libitum control diet was inserted to prevent any influence of a previous test. Fasted and nonfasted pretreatments were alternated, and no group of chickens received the same dietary treatment on two successive testing days. All results are means of eight repeating days of four observations per day.

Statistical Analysis. Data are indicated as mean ± SEM. In the second experiment, differences were tested between doses within each diet for fasted as well as for nonfasted chickens (letters). Differences were also tested between fasted and nonfasted chickens at each dose of each diet (asterisks). This was done by one-way ANOVA, using the general linear model procedure (SAS, 1986). If a significant effect ($p < 0.05$) of a classical variable was observed, means were contrasted by Duncan's multiple range test.

RESULTS

Experiment 1. In the control groups (C-C), the average daily feed intake from feeders 1 and 2 was 55.08 (±1.65)% and 44.92 (±1.65)% of total daily feed intake, respectively (Figure 1). In the JO-C groups the average daily feed intake from the jojoba-rich meal (feeder 1) was 17.2 (±2.1)% of total daily feed intake. The average daily feed intake from the commercial diet (feeder 2) was 82.8 (±2.1)% of total daily feed intake (Figure 2). The average total daily feed intake (sum of both feeders) from the JO-C groups was 90 (±0.9)% of the average total daily feed intake from the C-C groups. At 6 weeks of age the mean body weight per chicken was 1.80 ± 0.01 kg in the C-C groups and 1.41 ± 0.11 kg in the JO-C groups.

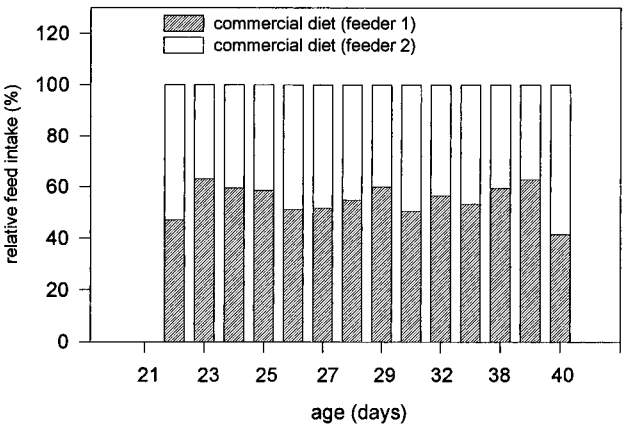

Figure 1. Average relative feed intake from the two feeders as a percentage of the total feed intake in the C-C treatments. Both feeders were filled with commercial diet.

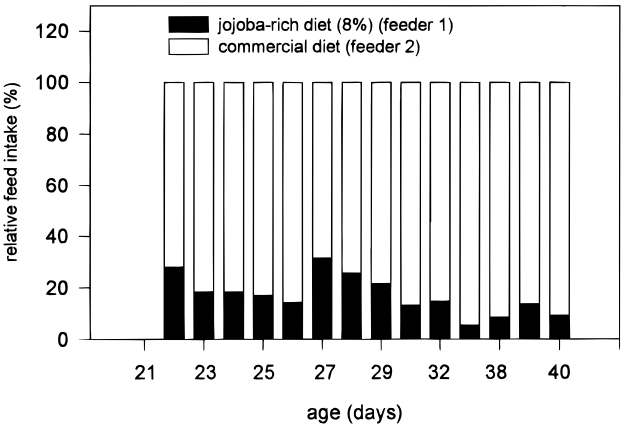

Figure 2. Average relative feed intake from the two feeders as a percentage of the total feed intake in the JO-C treatments. Feeder 1 was filled with a jojoba-rich diet (8%) and feeder 2 with a commercial diet.

Immediately after the feeders were moved, chickens were equally represented at the two feeders in all groups, whereas a few minutes later, in the JO-C groups, all chickens had rejected the jojoba-rich diet to choose the commercial diet.

Experiment 2. Figure 3 shows the average feed intake, expressed as a percentage of the average control feed intake in either fasted or nonfasted chickens. Data summarize feed intake 30 min after feed presentation to chickens treated with increasing concentrations of (A) ip injections of CCK-8, (B) quinine HCl supplementation in commercial feed, and (C) deoiled jojoba meal supplementation in commercial feed. After ip injection of CCK-8, the first 30 min feed intake, expressed as a percentage of control values, was reduced significantly in birds injected with 10, 20, and 40 μg of CCK-8/kg of body weight (BW) in nonfasted chickens, whereas in fasted chickens, this reduction in feed intake was only observed in chickens injected with 20 and 40 μg of CCK-8/kg. The effect of CCK-8 was more pronounced in nonfasted chickens compared with fasted chickens.

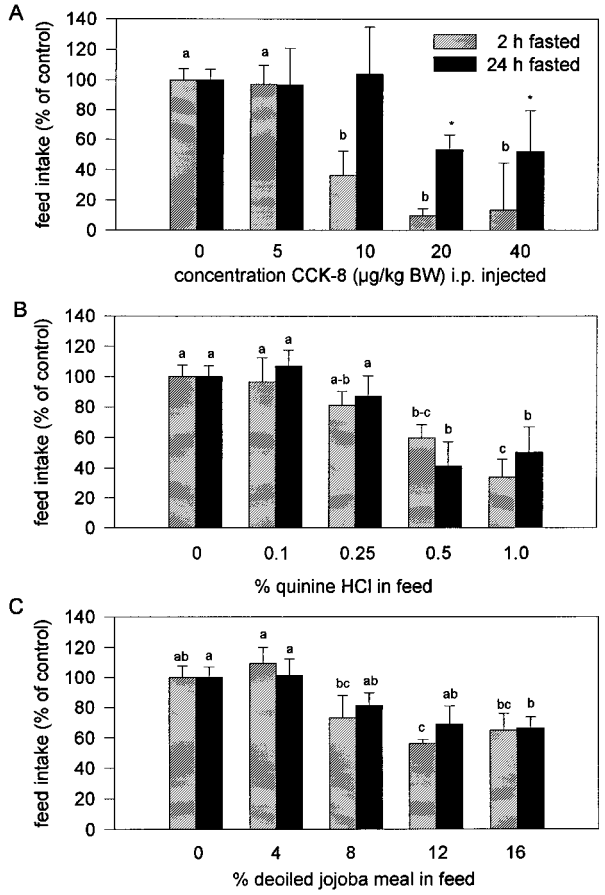

Figure 3. Feed intake, expressed as percentage of control values in fasted and nonfasted chickens, 30 min after feed presentation (0′−30′): effect of increasing concentrations of (A) ip injections of CCK-8, (B) quinine HCl in feed, and (C) deoiled jojoba meal in feed. Different letters indicate significant differences between different concentrations of CCK-8, quinine HCl, or deoiled jojoba meal; asterisks (*) indicate a significant difference between fasted and nonfasted chickens.

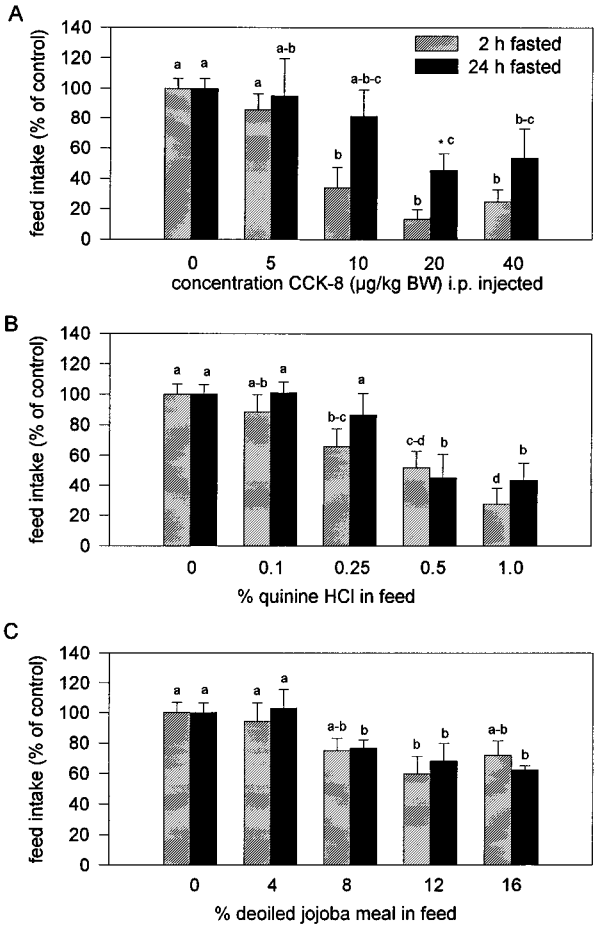

Figure 4. Feed intake, expressed as percentage of control values in fasted and nonfasted chickens, 60 min after feed presentation (0′−60′): effect of increasing concentrations of (A) ip injections of CCK-8, (B) quinine HCl in feed, and (C) deoiled jojoba meal in feed. Different letters indicate significant differences between different concentrations of CCK-8, quinine HCl, or deoiled jojoba meal; asterisks (*) indicate a significant difference between fasted and nonfasted chickens.

Injection of both 20 and 40 μg of CCK-8/kg of BW reduced feed intake of the nonfasted chickens to 15% of control feed intake but only to 50% of control feed intake in the fasted chickens. The difference between these two groups at both doses of CCK-8 was statistically significant (Figure 3A).

In both nonfasted and fasted chickens, which were presented with quinine HCl-supplemented feed, a dose dependent reduction of feed intake was observed. There was no difference between the reduction in feed intake of fasted and nonfasted chickens at any concentration (Figure 3B).

Increasing concentrations of deoiled jojoba meal also induced a dose dependent reduction in feed intake in both fasted and nonfasted chickens. A maximal effect was seen at a 12% JO supplementation. At 16% JO supplementation no additional reduction in feed intake was observed. In the jojoba meal-supplemented group, the reduction in feed intake of fasted and nonfasted chickens was equal (Figure 3C). Comparing the effects of CCK-8, QHCl, and JO supplementation, the effect of CCK-8 was significantly greater than that of JO at the maximal effective dose, especially in the nonfasted group, but there was no significant difference between JO and QHCl for both groups of chickens.

Comparable results are shown in Figure 4, in which the averages of the total first 60 min (0′−60′) feed intake are expressed as a percentage of control values for animals treated with different concentrations of CCK-8, quinine HCl, and deoiled jojoba meal. Again, dose dependent reductions in feed intake were observed in CCK-8-treated birds as well as in birds fed with a quinine HCl- or jojoba-supplemented diet. The difference between fasted and nonfasted chickens after CCK-8 injection during the first 30 min after feed presentation was still observed during the total first 60 min. Yet, this difference was only statistically significant at a dose of 20 μg of CCK-8/kg of BW. Again, for the quinine HCl- as well as for the jojoba-supplemented group, no statistically significant difference was seen between the feed intake reduction in fasted and nonfasted chickens.

Figure 5 shows the averages of feed intake for 30 min (60′−90′), during which all groups of chickens received ad libitum commercial feed again. At the highest concentrations of CCK-8 (20 and 40 μg/kg of BW), a strong reduction in feed intake, as a percentage of the control feed intake, was still observed (Figure 5A). At the dose of 20 μg/kg of BW, the difference in feed intake between fasted and nonfasted chickens was still present. In the groups of chickens previously fed commercial diet containing different concentrations of quinine HCl, feed intakes were similar to those of controls in both fasted and nonfasted birds (Figure 5B). The reduction in feed intake disappeared as soon as the presentation of the unpalatable tasting agent, quinine HCl, was removed.

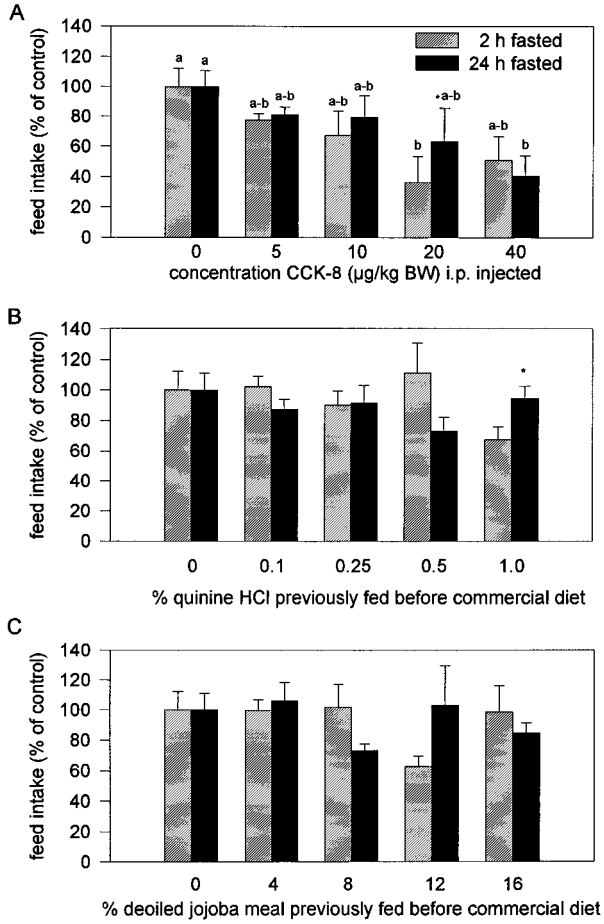

Figure 5. Feed intake, expressed as percentage of control values in fasted and nonfasted chickens, for 30 min (60′−90′) during which they received ad libitum commercial feed after (A) previous increasing ip injections of CCK-8, (B) previous feed presentation of increasing concentrations of quinine HCl in feed during the first hour, and (C) previous feed presentation of increasing concentrations of deoiled jojoba meal in feed during the first hour. Different letters indicate significant differences between different concentrations of CCK-8, quinine HCl or deoiled jojoba meal; asterisks (*) indicate a significant difference between fasted and nonfasted chickens.

Figure 5C shows similar intake of feed between chickens that were previously exposed to JO meals and controls. After withdrawal of the jojoba-mixed feed, the feed intake inhibition stopped immediately at almost all concentrations of previously fed jojoba meal. There was no statistically significant difference between the animals previously fed feed supplemented with different concentrations of JO. Neither was there any statistical difference between fasted and nonfasted chickens.

DISCUSSION

In the preference trial (experiment 1), all JO-C chickens rejected the jojoba-rich diet to choose the commercial diet almost immediately after presentation of both feeders. These observations suggest that jojoba has a negative taste effect on feed intake in broilers. In contrast, if the choice of feed is determined by metabolic reactions of certain feed components, some time would be necessary before a choice can be made.

Consequently, within the JO-C groups, average daily feed intake from the jojoba-rich diet was much lower than the daily feed intake from the commercial diet. This reduced feed intake of JO points again to an unpalatable taste effect of the jojoba meal. Under conditions with only one feed available (C-C), the birds do not prefer one feeder over the other, although, yet, there was a slight preference for feeder 1. It is not excluded that the unpalatable taste is not the only reason why they eat less from the JO feeder than from the C feeder. If the birds would have a satiated feeling after uptake of the jojoba meal, they would not spend as much time at the JO feeder as they would normally, when they are not satiated. As a consequence, in case of satiation, total feed intake from the JO feeder would be lower than that from the C feeder. Therefore, a possible satiation effect of jojoba meal still can not be excluded, unless total daily feed intake is the same in both JO-C and C-C groups. Total feed intake of the JO-C groups was a little lower—but not significantly different—from that of the C-C groups. This small difference in total feed intake could be explained by a slight satiaton effect or, alternatively, could be the consequence of a slightly impaired body weight gain after 6 weeks due to decreased digestibility caused by some antinutritional factors in jojoba meal, such as tannins, phytic acid, and trypsin inhibitors (Wiseman and Price, 1987). Indeed, the observation that the feed intake from the JO feeder slightly decreased with increasing age also indicates that an aversion effect of jojoba meal is not excluded. The chickens possibly had learned to associate the taste of the jojoba meal with some adverse effects.

From the second experiment, it may be concluded that deoiled jojoba meal caused reduced feed intake activity by its unpalatable taste rather than by inducing satiety, following the rationale of Billington *et al.* (1983). During the 30 and 60 min treatments, the chickens reacted to jojoba meal in a similar way as to a quinine HCl supplementation, *i.e.*, in a way that could be predicted from substances inducing taste aversion (Figures 3 and 4). The reduction in feed intake in JO-treated chickens disappeared as soon as the jojoba-rich diet was replaced by control feed (Figure 5C). A similar result was obtained after replacing the feed supplemented with the unpalatable tasting quinine HCl by control feed. Therefore, it is concluded that jojoba meal reduces feed intake by its unpalatable taste, rather than by inducing satiation, in contrast to the results obtained in rats by Cokelaere *et al.* (1995a,b) who describe a satiating effect of simmondsin most probably by CCK. If jojoba and/or simmondsin would stimulate endogenous CCK in chickens, this satiating effect of CCK would not have ceased immediately after withdrawal of the jojoba-rich diet in experiment 2. In comparison, after injection of exogenous CCK-8, reductions of feed intake were still observed after 90 min. Moreover, although it is known that peripheral injections of exogenous CCK-8 decrease feed intake in chickens (Savory and Gentle, 1983), it is still not clear whether or not endogenously released CCK also decreases feed intake. Choi *et al.* (1994) postulated that, in contrast with mammals, endogenous CCK is not a major regulator of feed intake in poultry. It has also been demonstrated that, in chickens, CCK receptors have marked differences in their sensitivity to CCK antagonists in comparison with mammals (Furuse *et al.*, 1996). It is suggested that there exist at least two distinct CCK receptors in birds and that these receptors are relatively different from those described in mammals (Rodriguez-Sinovas *et al.*, 1995). In birds, it is possible that crop emptying rate may have a greater effect on feed intake than does CCK (Barbato *et al.*, 1994).

These differences in the control of voluntary feed intake between mammals and chickens can explain why our observations in chickens are in contrast with those of Cokelaere *et al.* (1995b) in rats. They observed that supplementation of feed with increasing doses (3%, 5%, and 10%) of deoiled jojoba meal induced a more pronounced dose dependent feed intake reduction in nonfasted than in fasted rats, which is typical for satiety agents. In rats, it was concluded that this reduction in feed intake was induced by the satiating effect of simmondsins, which may interact with the CCK system (Cokelaere *et al.*, 1995a). In contrast with the effect in rats, pure simmondsin does not have an anorexic effect in chickens (Vermaut *et al.*, 1996).

From the present results, it is concluded that in chickens the anorexic effect of deoiled jojoba is mainly due to palatability factors and not to the induction of satiation (as described in rats). Chickens have a keen sense of taste (Gentle, 1971). The concentration of an aversive agent required to depress feed intake of chickens without any alternative feed source is much higher than the concentration which is required to establish the same reduction in feed intake when choice is given (Kare and Pick, 1960). This explains why the effect on reduction in feed intake of a similar concentration of jojoba meal (8%) is more pronounced in the preference trial than in the second experiment.

Polyphenols (such as tannins), phytic acid, trypsin inhibitors, and unpalatable tasting substances may contribute to the impaired feed intake and body weight gain of jojoba-fed animals (Wiseman and Price, 1987). Tannins are polyphenolic compounds, known for their bitter taste. The levels of condensed tannins in the deoiled Israeli jojoba meal and the hull of the jojoba nut were respectively 1.75 g/100 g and 4.85 g/100 g as assayed by the method of Randolph (1995). This level in the skin is comparable with the level of Alfred faba beans (5.77 g/100 g of hulls), a variety which belongs to faba beans with a high tannin content (Bos *et al.*, 1989). Tannins are known to depress weight gain and increase feed conversion or decrease feed efficiency by reducing the digestibility of proteins in broilers in a dose dependent way (Mahmood and Smithard, 1993). Moreover, we have detected saponins in jojoba (unpublished results). Saponins are glycosides present in numerous plants and characterized by a bitter taste. Various reports mention that poultry is much more sensitive to saponins than other monogastrics and ruminants. Generally, saponins are considered to be less important because of the low levels in most common feed ingredients for monogastrics (Birk and Peri, 1980).

In conclusion, all the results of this study taken together point to a taste effect—and not a satiation effect—which is responsible for reduced intake of jojoba meal in poultry.

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