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The aim of this work was to study the effects of incorporating sugar beet pulp (SBP) into the diet on the development of the crop and performance of geese. A total of 480 1-day-old ganders were divided into three groups differing in the composition and mode of distribution of the diet offered from day 56 to 89. The following two diets were used: a standard diet (nitrogen-corrected apparent metabolizable energy, AME_n 11.44 MJ/kg; 160 g/kg CP) or a diet containing 10% of SBP (SBP diet; AME_n 11.47 MJ/kg; 160 g/kg CP). The swelling capacity (SC) hydration was higher for SBP than for the standard diet (3.62 v. *2.72 ml of H_2O/g of dry matter at 60 min;* $P < 0.05$*). In the Control group, birds were fed with a controlled time of access to a standard diet. Other birds were fed the SBP diet with a controlled time of access (SBPt group) or a controlled quantity offered (SBPq). From day 90 to 104, 88 birds/group were overfed with a mixture containing mainly corn. Body traits including volume of the crop were measured at day 89. Fatty liver weight and commercial grading were measured at d 104. Feed intake from day 56 to 89 was higher in the Control group than in the SBPt group (8097* v. *7545 g;* $P < 0.05$*), feed intake in the SBPq group being intermediate (7801 g); however, live weights (LW) of the birds were similar in the three groups measured at day 89 (5746 g;* $P > 0.05$*). At day 89, the volume of the crop tended to be higher in the SBPt compared with the Control group (52.8* v. *48.8 ml/kg of LW;* $P = 0.101$*). After overfeeding, feed intake (12 922 g), weight gain (2412 g), LW (8170 g), fatty liver weight (875 g) and commercial grading of the fatty liver were similar (*$P > 0.1$*) for all the three groups. Therefore, SBP could help adapt the digestive tract of waterfowl to high feed intake through an increase in the crop volume, but its method of use – that is, level of incorporation and mode of distribution – should continue to be investigated.*

Keywords: geese, sugar beet pulp, crop, rearing, overfeeding

Implications

When rearing geese for fatty liver production, the feeding programme must prepare the digestive tract of the birds for high feed intake, mainly ensuring a sufficient development of the crop volume. Incorporation of sugar beet pulp (SBP) in the finisher diet increases its swelling capacity, affects the birds' feed intake during the finishing period and tends to increase the crop volume at the end of the rearing period. However, the mode of use of this by-product in the diet of geese should continue to be investigated, because the feeding strategy used in the present work, such as SBP incorporation rate or period of use, had no effect on performance during the overfeeding period.

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Introduction

The fatty liver (foie gras) production system is based on the spontaneous ability of waterfowl to hyperphagia and store fat in the subcutaneous tissue and liver (Pond, 1978; Guy *et al.*, 2013), probably linked to the migratory behaviour of their ancestors, which had the natural ability to over-consume food to store energy before long migrations (Odum, 1960). Producers have developed specific feeding programmes to take advantage of this natural phenomenon (Guémené and Guy, 2004). However, fatty liver is controversial in animal science and society. There is a widespread lack of understanding and acceptance of the production system, as overfeeding is considered to be detrimental to animal welfare. Therefore, it seems necessary to improve this production system to respect societal demand. A natural morphological adaptation of the digestive tract to take in large amounts of feed would support a more animal-friendly production system. In this way, Arroyo *et al.* (2012b) have previously shown in goose species that a sufficient development of the crop is necessary to obtain good performance during the overfeeding period. Therefore, in present farming systems for fatty liver production, the feeding programme is managed to stimulate the crop development, mainly by changing the time of access to the feeder or the quantity of food offered to birds during the end of the rearing period, called the finishing period (Arroyo *et al.*, 2012a).

Arroyo *et al.* (2012b) showed that crop volume is affected by the hydration capacity of diet. Dried sugar beet pulp (SBP), a by-product of sugar beet, has a high water-holding capacity (WHC; Giger-Reverdin, 2000), and thus may be of interest in goose feeding to help the development of the crop and stimulate feed intake in a natural way. Most of the work on the use of this by-product in the diet of geese has been carried out on geese destined for meat production (Arslan, 2003; Arslan, 2004). It shows that incorporation of SBP, at a proportion of 10% to 15%, induced a high spontaneous feed intake leading to leaner birds having a more developed intestinal tract (Arslan and Saatci, 2003) without detriment to growth rate (Arslan, 2005). However, no data are available on the use of SBP in the diet of geese reared for fatty liver production.

Therefore, the aim of this work was to study the combined effects of the mode of distribution of the diet and SBP incorporation in the finisher diet of geese on development of crop, feed intake, growth and fatty liver weight and quality in geese reared for fatty liver production.

Materials and methods

Birds and feeding programmes

The animals were cared for in accordance with the guidelines for animal research of the French Ministry of Agriculture. Investigators were certified by the French governmental authority for carrying out these experiments (agreement n°31–11.43.501). This trial was carried out at the Goose and Duck Breeding Station (Coulaures, Dordogne, France) with Greylag ganders (*Anser anser*; line Maxipalm®). A total of 480 1-day-old ganders were divided into three groups (four pens of 40 birds per group) differing in the composition and mode of distribution of the finisher diet (distributed from day 56 to 89). The feeding programme was similar in all the three groups from day 1 to 55 and from day 90 to 104. All diets used during the rearing period met the NRC requirements (National Research Council (NRC), 1994) and were manufactured by Sanders Centre Auvergne (Aigueperse, France). Until day 55, the birds were subjected to a standard feeding programme as described by Arroyo *et al.* (2012a). In brief, birds were fed a pre-starter diet (nitrogen-corrected apparent metabolizable energy, AME_n 11.72 MJ/kg, 220 g/kg CP) from day 1 to 10, a starter diet (AME_n 11.72 MJ/kg, 200 g/kg CP) from day 11 to 28 and a grower diet (AME_n 12.14 MJ/kg, 180 g/kg CP) from day 29 to 55. Between day 56 and 89, the following two diets were used: a standard diet (AME_n 11.44 MJ/kg; 160 g/kg CP) or a diet containing 10% of SBP (SBP diet, AME_n 11.47 MJ/kg; 160 g/kg CP; Table 1). In the Control group, birds were fed the standard diet and had a controlled time of access to the feeder: 4 h/day (2 h in the morning and 2 h in the afternoon) from day 56 to 62; 2 h/day from day 63 to 87; and 3 h/day from day 88 to 89. Other birds were fed the SBP diet and had a controlled time of access to the feeder (SBPt group, exactly as those in Control group) or a controlled quantity of feed (SBPq group), corresponding to 95% of theoretical needs distributed once a day (Table 2) according to standard practice described by Guéméné and Guy (2004).

From day 90 to 104, 88 birds/group were overfed a mixture of 340 g of corn flour, 240 g of whole corn, 400 g of water and 20 g of vitamins (E: 32.00 UI/kg; B1: 4.00 mg/kg; K3: 2.86 mg/kg) and minerals ($FeSO_4$: 55.40 mg; $CuSO_4$: 15.00 mg, $ZnSO_4$: 40.00 mg; $MnSO_4$: 74.00 mg; Ca: 2.13 g,

Table 1 *Ingredients and chemical composition of the two experimental diets*

Items	Diet: Control diet	Diet: SBP diet
Ingredients (%)		
Corn	32.1	37.4
Wheat	38.0	29.7
Sugar pulp beet	–	10.0
Soyabean meal	6.0	–
Sunflower cake	11.0	–
Defatted rapeseed meal	4.4	4.4
Corn distillers	3.0	3.0
Corn gluten	–	10.0
Calcium carbonate	2.4	1.6
Dicalcium phosphate	1.8	2.0
Salt	0.2	0.2
Lysine	0.3	0.5
Vitamin and mineral premix[1]	0.8	1.2
Chemical composition (% in feed as fed)		
AME_n (MJ/kg as fed)	11.44	11.47
CP	16.0	16.0
Dry matter	87.5	89.2
Ash	5.7	5.6
Organic matter	81.8	81.9
Crude fibre	4.6	4.2
Cellulose	4.0	3.7
Hemicellulose	7.4	8.0
NDF	13.0	13.2
ADF	5.6	5.2
ADL	1.6	1.5
Lysine[2]	0.8	0.9
Methionine[2]	0.5	0.5
Methionine + cystine[2]	0.8	0.8
Threonine[2]	0.5	0.6

AME_n = nitrogen-corrected apparent metabolizable energy.
[1]Vitamins: A: 9990 IU/kg; D_3: 1998 IU/kg; E: 10 IU/kg; B_1: 2.0 mg/kg; K_3: 1.0 mg/kg; B_2: 2.5 mg/kg; B_5: 5.1 mg/kg; B_6: 1.0 mg/kg; PP: 24.9 mg/kg; B_9: 0.3 mg/kg; choline: 300 mg/kg. Oligo elements, Cu: 9.3 mg/kg; Fe: 29.0 mg/kg; I: 0.99 mg/kg; Co: 0.16 mg/kg; Mn: 70 mg/kg; Zn: 47 mg/kg; Se: 0.20 mg/kg; clay (sepiolite): 2 g/kg.
[2]Calculated from Sauvant *et al.* (2004).

Table 2 *Feeding programmes in the groups[1] used during the experiment*

Period	Pre-starting	Starting	Growing	Finishing		
Day	1 to 10	11 to 28	29 to 55	56 to 62	63 to 87	88 to 89
Group						
Control	*Ad libitum*	*Ad libitum*	*Ad libitum*	4 h/day	2 h/day	3 h/day
SBPq	*Ad libitum*	*Ad libitum*	*Ad libitum*	95% of theoretical needs		
SBPt	*Ad libitum*	*Ad libitum*	*Ad libitum*	4 h/day	2 h/day	3 h/day

SBP = sugar beet pulp.
[1]Control group: birds have a controlled time of access to the control diet; SBPt group: birds have a controlled time of access to the SBP diet; SBPq: birds have a controlled quantity of SBP diet.

Table 3 *Physical characteristics of the two experimental pellets*

Items	Diet		s.e.m.	Significance
	Standard	SBP		
Length (mm)	9.0	8.0	0.2	**
Diameter (mm)	3.0	3.0	0.0	ns
Hardness (kg)	6.39	6.94	0.2	0.074
Feedstuff hydration				
WHC (g of H_2O/g of dry matter)	1.67	2.10	0.11	ns
SC (ml of H_2O/g of dry matter)				
After 5 min	1.41	1.67	0.12	ns
After 10 min	1.69	2.51	0.22	*
After 15 min	2.06	3.06	0.24	**
After 20 min	2.44	3.43	0.25	*
After 25 min	2.44	3.62	0.29	*
After 30 min	2.63	3.62	0.27	*
After 40 min	2.72	3.62	0.23	*
After 50 min	2.72	3.62	0.23	*
After 60 min	2.72	3.62	0.23	*

s.e.m. = standard error of the mean; WHC = water-holding capactiy; SC = swelling capacity.
$^{**}P < 0.01$; $^{*}P < 0.05$; ns, $P > 0.2$.

Na: 1.44 g; P: 0.23 g/kg) per kg, according to the standard practices (Arroyo *et al.*, 2012a). The diet was distributed with an automatic feed dispenser (Gaveuse Mg 300, Dussau, Distribution Sas, Pecorade, Landes, France) and according to the planned overfeeding programme described by Arroyo *et al.* (2013a). The birds used for overfeeding were chosen according to their live weight (LW) at day 89 to be representative of the LW variability within groups.

Housing and management conditions

During the rearing period, the birds were housed in pens of 19 m² containing 40 birds. The pens were equipped with two drinkers, three feeders and an outdoor access area (91.5 m²/pen). The geese had outdoor access between 0700 and 1800 h from day 30 to 89; however, from day 56 to 89, the duration of outdoor access was reduced because it was denied during the time when birds received experimental diets. The room temperature was maintained at 28°C from the 1st week after hatching and was subsequently gradually reduced to 20°C at day 30, after which no heat was provided.

During the overfeeding period, the 264 geese were housed in 24 3 × 1 m pens, each with 11 geese. Each pen was equipped with drinkers. The room was maintained at a maximum temperature of 20°C and a maximum relative humidity of 90%.

Measurements

The chemical composition of the experimental diets is shown in Table 1. The physical characteristics of the experimental diets are shown in Table 3. Length and diameter of the pellets were measured on 50 samples. The same samples were used to analyse the pellet hardness using standard methods (Thomas and van der Poel, 1996) with a 'Kahl'-type tester (Hardness tester, Amandus Kahl GmbH & Co., Hamburg, Germany). The hydration capacity was measured through the WHC (g of H_2O/g of dry matter) and the swelling capacity (SC, ml of H_2O/g of dry matter) as described by Giger-Reverdin (2000). To measure WHC, 2 g of feedstuff was mixed with 10 ml of distilled water. After 8 h at room temperature, the mixture was centrifuged (966 × **g** for 10 min at 20°C) and the supernatant was removed before weighing the hydrated pellets. To measure SC, 25 ml of distilled water at room temperature was added to 2 g of feedstuff. Volume of the hydrated pellets was measured 5, 10, 15, 20, 25, 30, 40, 50 and 60 min after water addition.

Birds were weighed individually at day 1, 28, 56, 70 and 89 after 18 h of fasting. LW at 104 days of age was measured after 8 h of fasting, because at the end of overfeeding fasting more than 8 h leads to a decreased fatty liver weight (Leprettre *et al.*, 1998). Mortality was recorded daily throughout the experiment. Feed intake was measured weekly from day 1 to 89 (a measure per pen) and daily from day 90 to 104 (individual measurements).

At day 89, the crop volumes of 40 geese per group selected on their LW at day 89, according to the recommendations of Leprettre *et al.* (2002), were measured *in vivo* after 18 h of fasting, as described by Arroyo *et al.* (2012b). In brief, an inflatable balloon was gently introduced into the oesophagus and inflated to a constant pressure (70 mm Hg). The volume of air introduced was measured by displacement of a water column. Twelve geese per group were slaughtered at day 89 to study carcass traits according to the World's Poultry Science Association method (WPSA, 1984). The weights of the gut (small intestine, duodenum, jejunum, ileum and caecum), gizzard, liver, carcass (eviscerated carcass with skin) and abdominal fat were measured, as well as breast and thigh weights (without skin and subcutaneous fat).

At day 104, all geese (n = 88 per group at the beginning of overfeeding) were slaughtered after 8 h of fasting to measure the weight of fatty liver. The commercial grading of the fatty livers was carried out by an industry professional (Coopérative Sarlat Périgord, Sarlat-la-canéja, Dordogne, France) trained to classify the raw fatty livers according to their potential commercial use, as described by Arroyo *et al.* (2013a and 2013b). The livers were graded using a three-point scale: Class 1 corresponded to the best commercial class for livers with no defects, appropriate texture, usually processed as entire canned livers; Class 2 corresponded to livers with no external defects but too heavy (>900 g) to be processed as entire canned livers; and Class 3 livers had several defects in appearance or texture.

In this experiment, all birds were killed according to the European council regulations (EC, 2009).

Statistical analysis
Data were analysed using PASW Statistics18 for Windows (version 18.0.2, SPSS Inc., Chicago, IL, USA). Performance of geese (except mortality rate and fatty liver commercial grading) was first analysed using the GLM procedure, using the following equation:

$$Y_{ij} = \mu + G_i + P_j + (G_i \times P_j) + \varepsilon_{ij}$$

where Y is the dependent variable; μ the overall mean; G_i the effect of group (three levels: control, SBPt and SBPq); P_j the effect of pen (12 levels); $(G_i \times P_j)$ the interaction between group and pen; and ε_{ij} the error.

However, the effects of pen (P_j) and the interaction ($G_i \times P_j$) were not significant (data not shown), and were, thus, removed from the final model, which was finally $Y_i = \mu + G_i + \varepsilon_i$. Physical characteristics of the diets (length, diameter, WHC, SC, hardness) were analysed using the following equation:

$$Y_i = \mu + D_i + \varepsilon_i$$

where Y_i is the dependent variable; μ the overall mean; D_i the effect of diet (two levels: standard diet and SBP diet); and ε_i the error.

When significant, differences between treatments were compared using Duncan's test. The fatty liver commercial grading and mortality during the rearing and overfeeding periods were analysed using a χ^2-test. Differences were treated as significant when $P \leqslant 0.05$.

Results

Physical characteristics of experimental diets
The diameter of the pellets was similar in the Control and the SBP diets (3.00 mm; $P > 0.2$; Table 3), but the pellets were longer for the Control than for SBP diet (+13%; $P < 0.01$). The hardness tended to be higher in SBP compared with the Control diet (6.94 *v.* 6.39 kg; $P = 0.074$; Table 3). WHC tended to be higher in SBP than in the Control diet (+25%; $P = 0.104$). SC was higher in SBP than in the Control diet from 10 min (+48%; $P < 0.05$) until 60 min after water addition (+33%; $P < 0.05$). The swelling volume maximum was reached faster for SBP compared with the Control diet (25 *v.* 40 min; Table 3).

Feed intake during the rearing period
From day 1 to 55, the feed intake was similar in all the three groups ($P > 0.05$, Table 4). In contrast, feed intake from day 56 to 89 was highest in the Control group (8097 g) and lowest in the SBPt group (7545 g), feed intake in the SBPq group being intermediate (7801 g; $P < 0.05$). Effect of SBP incorporation in the diet on feed intake was dependent on the mode of distribution of the diet, as feed intake was lowest in the SBPq group from day 56 to 62 and highest from day 71 to 83. Over the entire rearing period – that is, from day 1 to 89 – feed intake of the birds was similar in all the three groups (22 281 g; $P > 0.2$; Table 4).

Mortality and bird growth during the rearing period
Mortality during the rearing period tended to be similar in all the three groups (0.3%; $P = 0.081$). The LW were similar ($P > 0.2$) in the three groups throughout the rearing period (110, 2422, 5335 and 5746 g at day 1, 28, 56 and 89, respectively), except at day 70 when the birds were lighter in the SBPq compared with the other two groups (5507 *v.* 5680 g; $P < 0.001$).

From day 56 to 70, the average daily gain (ADG) was lower in the SBPq group compared with the SBPt and Control groups (11.5 *v.* 20.9 and 24.7 g/day, respectively; $P < 0.001$). Conversely, from day 70 to 89, ADG was higher in the SBPq group than in the other two groups (14.0 *v.* 2.9 g/day; $P < 0.001$, Table 5). Over the entire rearing period – that is, from day 1 to 89 and from day 56 to 89 – the feed conversion

Table 4 *Average daily (g/day) and cumulative (g/bird) feed intake of geese during the rearing period* [1]

	Group[2]				Significance
Period	Control	SBPt	SBPq	s.e.m.	Group
Day 1 to 6	46	47	46	1	ns
Day 7 to 13	115	127	117	3	ns
Day 14 to 20	241	240	232	3	ns
Day 21 to 27	225	223	225	2	ns
Day 28 to 35	350	362	342	5	ns
Day 36 to 41	360	361	358	2	ns
Day 42 to 48	389	388	392	6	ns
Day 49 to 55	334	337	350	5	ns
Day 56 to 62	338^{a}	340^{a}	241^{b}	14	***
Day 63 to 70	226^{ab}	218^{b}	230^{a}	2	*
Day 71 to 76	217^{b}	201^{c}	246^{a}	6	***
Day 77 to 83	201^{b}	183^{c}	214^{a}	4	***
Day 84 to 89	260^{a}	215^{b}	258^{a}	8	*
Finishing period (day 56 to 89)	8097^{a}	7545^{b}	7801^{ab}	95	*
Overall rearing period (day 1 to 89)	22 499	22 126	22 218	131	ns

s.e.m. = standard error of the mean; SBP = sugar beet pulp.
[a,b,c]Within a row, means with no common superscript differ at $P < 0.05$.
[1]The individual feed intake was calculated from the intake per pen (n = 4 pens/group) and the numbers of birds in the pen during the period (40 birds per pen at the beginning of the experimental period).
[2]Control group: birds have a controlled time of access to the control diet; SBPt group: birds have a controlled time of access to the SBP diet; SBPq: birds have a controlled quantity of SBP diet.
***$P < 0.001$; *$P < 0.05$; ns, $P > 0.2$.

Table 5 *Average LW, ADG and FCR*[1] *of geese during the rearing period*

	Group[2]				Significance
Items	Control	SBPt	SBPq	s.e.m.	Group
LW (g)					
Day 1	109.3	110.9	110.7	0.4	ns
Day 28	2399	2438	2429	9	ns
Day 56	5332	5336	5338	18	ns
Day 70	5709^{a}	5650^{a}	5507^{b}	21	***
Day 89	5762	5698	5779	22	ns
ADG (g/day)					
Day 1 to 28	81.8	83.1	82.8	0.3	ns
Day 28 to 56	104.8	103.4	103.8	0.5	ns
Day 56 to 70	24.7^{a}	20.9^{b}	11.5^{c}	0.6	***
Day 70 to 89	3.0^{b}	2.8^{b}	14.0^{a}	0.5	***
Day 1 to 89	62.8	62.1	63.0	0.2	ns
FCR					
Day 1 to 56	2.76	2.79	2.76	0.02	ns
Day 56 to 70	10.10^{b}	11.69^{b}	23.37^{a}	2.15	**
Day 56 to 89	19.71	21.26	18.20	1.04	ns
Day 1 to 89	3.99	3.96	3.92	0.03	ns

s.e.m. = standard error of the mean; ADG = average daily gain; LW = live weight; FCR = feed conversion ratio; SBP = sugar beet pulp.
[a,b,c]Within a row, means with no common superscript differed at $P < 0.05$.
[1]FCR per bird was determined using measured LW (individual measure) and estimated feed intake (measure per pen).
[2]Control group: birds have a controlled time of access to the control diet; SBPt group: birds have a controlled time of access to the SBP diet; SBPq: birds have a controlled quantity of SBP diet.
***$P < 0.001$; **$P < 0.01$; ns, $P > 0.2$.

ratio (FCR) was similar in all the three groups (3.96; $P > 0.2$ and 19.72; $P > 0.2$, respectively; Table 5).

Body traits at the end of the rearing period

At day 89, the crop volume tended to be higher in SBPt than in the Control group (52.8 *v.* 48.8 ml/kg of LW, $P = 0.101$). The liver was heavier in the Control group than in the other two groups (+10%; $P < 0.05$), and the gizzard was heavier in the Control group than in the SBPt group (+12%; $P < 0.05$). The gizzard in the SBPq group was intermediate (3.93% of LW). The other body traits were similar in all the three groups (Table 6).

Table 6 *Effect of dried sugar beet pulp in the finisher diet on geese carcass composition at day 89*

	Group[1]				Significance
Items	Control	SBPt	SBPq	s.e.m.	Group
Day 89 (n = 16/group)					
LW (g)	5730	5718	5761	58	ns
Carcass (g)	3183	3224	3202	36	ns
Liver (% of LW)	1.63[a]	1.47[b]	1.50[b]	0.02	*
Gizzard (% of LW)	4.23[a]	3.79[b]	3.93[ab]	0.07	*
Gut (% of LW)	4.69	4.50	4.54	0.07	ns
Abdominal fat (% of LW)	2.51	2.74	2.58	0.07	ns
Pectoral muscle (% of carcass)	7.77	7.99	7.79	0.08	ns
Thigh with bones[2] (% of carcass)	11.73	11.64	10.83	0.25	ns
Volume of crop (ml/kg of LW)	48.8	52.8	49.2	0.8	0.101

SBP = sugar beet pulp; s.e.m. = standard error of the mean; LW = live weight.
[a,b]Within a row, means with no common superscript differed at $P < 0.05$.
[1]Control group: birds have a controlled time of access to the control diet; SBPt group: birds have a controlled time of access to the SBP diet; SBPq: birds have a controlled quantity of SBP diet.
[2]Without skin and subcutaneous fat.
*$P < 0.05$; ns, $P > 0.2$.

Table 7 *Performance traits of geese before, during and after overfeeding*

	Group[1]				Significance
Items	Control	SBPt	SBPq	s.e.m.	Group
Number of birds at day 90	88	88	88		ns
Number of birds at day 104	84	84	84		
LW at day 89 (g)	5744	5,719	5759	25	ns
Feed intake[2] from day 90 to 104 (g)	12 980	12 799	12 988	79	ns
Weight gain day 90 to 104 (g)	2401	2442	2394	13	ns
FCR day 90 to 104	5.50	5.39	5.52	0.03	ns
LW at day 104 (g)	8162	8177	8172	26	ns

SBP = sugar beet pulp; s.e.m. = standard error of the mean; FCR = feed conversion ratio; LW = live weight; s.e.m. = standard error of the mean.
[1]Control group: birds have a controlled time of access to the control diet; SBPt group: birds have a controlled time of access to the SBP diet; SBPq: birds have a controlled quantity of SBP diet.
[2]Without water.
ns, $P > 0.2$.

Bird performance during and after overfeeding
Mortality was similar in all the three groups throughout the overfeeding period (4.5%, $P > 0.2$). Feed intake (12 922 g; $P > 0.2$), weight gain (2412 g; $P > 0.2$), FCR (5.47; $P > 0.2$) and LW at the end of the overfeeding period (8170 g; $P > 0.1$; Table 7) were similar in the three groups. The weight (875 g; $P > 0.2$) and commercial grading of the fatty livers ($P > 0.2$; Table 8) were similar in all the three groups.

Discussion

Greylag geese are mainly reared for fatty liver production, and the feeding programme of birds is intended to prepare them for overfeeding (Guémené and Guy, 2004) – that is, to consume a large amount of food in a short period of time. The development of the crop is a key feature of fatty liver production systems, especially in goose species in which the crop is not a truly differentiated organ (Sturkie, 1986), but rather an extension of the oesophagus in the form of a pocket produced especially under the effect of the diet. The objective of the experiment was to study the effect of a 10% incorporation of SBP in the finisher diet on hydration capacity of the diet and body development including crop volume and performance of geese during finishing and overfeeding periods. The underlying hypothesis concerned the ability of SBP to naturally adapt the digestive tract of birds to high feed intake, because of its high WHC.

Incorporation of SBP at a proportion of 10% has a strong influence on the SC of the diet (+25% for WHC and +48% for SC at 10 min), as shown previously (Giger-Reverdin, 2000). Nevertheless, WHC of the two experimental diets was lower than that reported by Arroyo *et al.* (2012b) for a diet offered to finishing geese (2.33 *v.* 1.67 g of H_2O/g of dry matter in both control diets). This can be explained by the composition, the hardness (Hansen and Storebakken, 2007; Samuelsen *et al.*, 2013) and/or particle size of the diets used

Table 8 *Effect of dried sugar beet pulp in the finisher diet of geese on fatty liver quality before cooking*

	Group[1]				Significance
Item	Control	SBPt	SBPq	s.e.m.	Group
Fatty liver					
Fatty liver weight (g)	862	899	865	12	ns
Commercial grading[2] (%)					
Class 1	75	81	81		ns
Class 2	13	13	15		
Class 3	12	6	4		

s.e.m. = standard error of the mean; SBP = sugar beet pulp.
[1]Control group: birds have a controlled time of access to the control diet; SBPt group: birds have a controlled time of access to the SBP diet; SBPq: birds have a controlled quantity of SBP diet.
[2]Class 1: livers with no defects and <900 g; Class 2: heavy livers (>900 g) with no external defects; Class 3: livers with several defects in appearance or texture.
ns, $P > 0.2$.

in our experiment. Indeed, Raghavendra *et al.* (2004) showed that hydration capacity increased when particles increased from 400 to 600 μm but decreased above 600 μm.

A relationship between hydration capacity of the diet and crop volume at the end of the growing period has previously been shown in geese (Arroyo *et al.*, 2012b). In the present study, SBP incorporation had a small effect on crop volume, but, independently of the group, the crop volume was higher (48.8 to 52.8 ml/kg of LW) compared with that previously reported by Arroyo *et al.* (2012b; 42.2 to 48.5 ml/kg of LW) with the same line of geese.

SBP incorporation reduced the weight of gizzard and liver before overfeeding, independently of the mode of distribution of the diet (restricted quantity or of time access). This may be because of differences in the size of particles and/or the greater hardness of the SBP diet compared with standard diet, as previously shown (Amerah *et al.*, 2007; Abdollahi *et al.*, 2013). Gizzard weight was reduced when birds had a controlled time of access to the SBP diet (SBPt group). This may result from an interaction between diet composition and its mode of distribution on feed intake, which was lower in the SBPt group than the SBPq group in several periods. We hypothesized that because of its high SC, the SBP diet fills the oesophagus more quickly than the Control diet, accelerating the onset of satiety. When the time of access to the feeder is restricted (as in SBPt group), access to the feeder was denied even when hunger returned, leading to a reduced feed intake.

The present results show that SBP incorporation did not reduce the growth of geese during the finishing period, as previously shown in geese reared for meat production (Arslan, 2003; Arslan, 2005). Furthermore, SBP incorporation decreased the feed intake of geese having a controlled time of access to the diet during the finishing period. This is at variance with the results of Arslan and Saatci (2003) obtained in geese reared for meat production. This suggests that the value of SBP in increasing feed intake in growing geese may not be applicable during restricted feeding. The influence of SBP in a finishing diet provided *ad libitum* on feed intake and subsequent performance of geese during overfeeding needs, therefore, to be studied. However, the energy content of the finishing diet should be low, as high subcutaneous or abdominal fat deposition before the overfeeding period reduces performance during that period (Arroyo *et al.*, 2012b).

SBP incorporation in the finisher diet had no influence on performance (feed intake, weight gain, fatty liver quality) during the overfeeding period. Arroyo *et al.* (2012b) have previously shown that the mortality is negatively related to crop volume. Therefore, in the present study, slightly larger crop volumes of birds might have reduced mortality, but it was not the case. However, the mortality observed in the present study was already considerably lower than that reported earlier (4.5% *v.* 9.8%).

Conclusions

The incorporation of SBP in the diets of finishing geese modified the physical characteristics of diet, mainly SC, and body traits of geese at the end of the rearing period. It had no effect on the birds' performances during growing or overfeeding periods. However, the mode of distribution of the diet interacted with its composition and influenced the feed intake of birds. Therefore, the way this by-product is used in the diet of geese grown for fatty liver production should be further investigated in order to improve its efficiency.

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