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Impact of sensory feed additives on feed intake, feed preferences, and growth of female piglets during the early postweaning period¹

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ABSTRACT: Our study aimed at investigating the effect of feed supplementation, from weaning, with 3 sensory feed additives (FA1, FA2, and FA3) on feed preferences, feed intake, and growth of piglets. The FA1 contained extract of *Stevia rebaudiana* (10 to 20%), extract of high-saponin plants (5 to 10%), and excipients (70 to 85%), the FA2 was mainly composed of a natural extract of *Citrus sinensis* (60 to 80%), and the FA3 was made of a blend of extracts of hot-flavored spices (5 to 15%) and excipients (85 to 95%). At weaning (d 1), a total of 32 female piglets housed in individual pens were allocated to 4 treatments (FA1, FA2, FA3, and control [CON]) of equivalent mean weight. The pigs were fed a standard pelleted prestarter diet from weaning (d 1) to d 15 and a starter diet from d 16 to 28. The diets were supplemented with the feed additives (FA) corresponding to their treatment, while the CON treatment was the standard diets with no additive. Feed refusals were weighed daily and piglets were weighed weekly on d 1, 7, 14, 21, and 28. On the day of feed transition (d 16) as well as 7 (d 23) and 10 d (d 26) later, the animals were consecutively subjected to 1- and 22-h double-choice feeding tests to investigate their preferences during a

short period and a longer period of time for the CON starter diet and the starter diet added with the FA corresponding to their treatment. No overall effect of the feed additives was observed on ADFI, ADG, G:F, and final BW. No overall preference was highlighted for the FA1 treatment, except for a preference for the FA1 starter diet during the 1-h test on d 23 (78% of total feed intake; $P < 0.01$). For the FA2 treatment, the pigs consumed the FA2 starter diet more than the CON starter diet during the 22-h tests on d 16 (67% of total feed intake; $P < 0.05$) and 26 (62% of total feed intake; $P < 0.01$). For the FA3 treatment, on d 26, the FA3 starter diet was and tended to be consumed more than the CON starter diet during 1- (69% of total intake; $P < 0.05$) and 22-h (60% of total intake; $P < 0.10$) tests, respectively. In conclusion, feed supplementation with the FA1, FA2, and FA3 from weaning did not induce beneficial effects on feed intake and growth performance during the early postweaning period. The FA2 increased palatability and acceptance of the unfamiliar starter diet the day of feed transition, while the FA1 and FA3 increased palatability of the starter diet only after a few days of exposure, most likely through long-term familiarization processes.

Key words: feed additives, feed transition, palatability, performance, piglet, preference

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INTRODUCTION

According to the definition of the European Commission, “feed additives are products used in animal nutrition for purposes of improving the quality of feed... or to improve the animals’ performance and health.” Sensory additives are a type of feed additive defined as “any substance, the addition of which to feed improves or changes the organoleptic properties of the feed” (regulation [European Community] number 1831/2003).

In pig production, sensory feed additives based on essential oils, aromatic herbs, and/or spices are commonly used in an attempt to improve feed palatability

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and zootechnical performance (feed intake and growth; Windisch et al., 2008; Franz et al., 2010; Jacela et al., 2010) and especially during sensitive/stressful periods such as weaning, environmental, or feed transitions during which feeding activity and growth can be severely impaired (Campbell, 1976; Dong and Pluske, 2007). Several studies have investigated the beneficial effects of feed supplementation with sensory additives on feed palatability, feed intake, and growth performance in pigs and reported contradictory results depending on the additive composition, inclusion rates, periods of exposure to the additive, or diet composition (e.g., Jugl-Chizzola et al., 2006; Seabolt et al., 2010; Clouard et al., 2012; Michiels et al., 2012).

This study was conducted to investigate the effects of feed supplementation with 3 sensory feed additives from weaning on feed intake, feed preferences, and growth performance of piglets during the early growing period. We hypothesized that exposure to the feed additives from weaning would enhance feed palatability and that 1) feed supplementation with the additives in a prestarter diet would result in preferences for a starter diet added with the same additives after a feed transition and 2) the pigs exposed to the feed additives would have greater feed intake and growth than pigs exposed to a standard diet with no additive.

MATERIALS AND METHODS

The experiment presented in this paper was conducted in accordance with the current ethical standards of the European Union (directive 2010/63/EU), agreement number 35-622, and authorizations number 35-88. The Regional Ethics Committee in Animal Experiment of Brittany has validated the entire procedure described in this paper (R-2012-DVL-02).

Animals and Housing

A total of 32 Large White/Landrace × Piétrain female pigs weighing 8.33 ± 0.14 kg at the beginning of the study were used. The pigs were weaned at 26.38 ± 0.09 d of age and housed in individual pens (80 by 60 by 68 cm) in 2 similar rooms with 16 pens per room and a natural day/night cycle. Each pen contained a 2-part feeder. The temperature of the 2 rooms was kept at $24.6 \pm 0.16^\circ\text{C}$ and $25 \pm 0.32^\circ\text{C}$, respectively. The animals had free access to water during the whole experiment.

Experimental Meals

Three sensory feed additives based on essential oil mixture and plant extracts (**FA1**, **FA2**, and **FA3**) were tested in this study. These additives were provided by a commercial

company specialized in sensory functional feed formulation (Laboratoires Phodé, Terssac, France). The FA1 contained extract of *Stevia rebaudiana* (10 to 20%) with a minimum of 90% steviol glycosides, extract of high-saponin plants (5 to 10%), and excipients (70 to 85%). The FA2 was mainly composed of a natural extract of *Citrus sinensis* (60 to 80%). The FA3 was made of a blend of extracts of hot-flavored spices (5 to 15%) and excipients (85 to 95%).

The pigs were fed a pelleted prestarter diet from weaning (d 1) to 15 d after weaning (d 15) and a pelleted starter diet from d 16 to the end of the study. The prestarter and starter diets were formulated so that the nutrient composition (other than total sulfur amino acids) met or exceeded recommendations of the NRC (1998) throughout the experimental period (Table 1). Six experimental diets were formulated by the adjunction of the 3 feed additives (FA1, FA2, and FA3) in the prestarter and starter standard diets. The 3 powdered feed additives were incorporated in a matrix of wheat middling and were added in the diets during the feed formulation process at 10 kg/t of feed, so as the inclusion rates of FA1, FA2, and FA3 were 0.4% (wt/wt), 0.003125‰ (wt/wt), and 0.0405‰ (wt/wt), respectively. The inclusion rates were chosen by our industrial partner (Laboratoires Phodé) and were justified by previous unpublished findings obtained in their laboratory on farm species and by a previous study of our group in pigs (Clouard et al., 2012). Additionally, 2 control (**CON**) diets were formulated by the addition of 10 kg/t of wheat middling with no additive in the prestarter and starter diets.

Experimental Design

Feed Intake and Growth. The day before weaning (d 0), the animals were allocated to 4 treatments of equivalent mean weight (FA1 treatment: 8.33 ± 0.22 kg, FA2 treatment: 8.33 ± 0.34 kg, FA3 treatment: 8.33 ± 0.24 kg, and CON treatment: 8.33 ± 0.41 kg). From weaning (d 1) to d 15, the pigs were fed the prestarter diet corresponding to their treatment, and from d 16 to the end of the study, the pigs were fed the starter diet corresponding to their treatment. However, during the double-choice feeding tests on d 16, 23, and 26, all the animals were also offered simultaneous access to the CON starter diet, in addition to the corresponding experimental starter diet (see below). The amount of feed distributed per day was adjusted so as to ensure that no feeder was emptied before the next feed provision (i.e., animals fed ad libitum). Each day, the animals had a 23-h access to feed, that is, from 1000 to 0900 h the next day. The feed was distributed 3 times a day at approximately 1000, 1300, and 1600 h and the left and right positions of the feed in the feeder were counterbalanced across days to habituate the animals to eat from both parts of the feeder. The daily feed refusals were weighed at 0900 h the next day. Also, the piglets were

Table 1. Composition of the standard prestarter and starter diets (as-fed basis)¹

Item	Diets	
	Prestarter diet	Starter diet
Ingredient, %		
Wheat	–	23.20
Corn	–	25.00
Barley	45.31	24.05
Soybean meal	17.50	22.57
Soybean proteins	2.50	–
Vegetal oil	2.30	0.45
Mild lactoserum	20.00	–
Fattened milk	8.00	–
Carbonate calcium	1.41	1.13
Monocalcic phosphate	0.80	0.97
Salt	–	0.40
Vitamin and mineral premix ²	0.50	0.50
L-Lysine HCl	0.41	0.78
DL-Methionine	0.26	0.20
L-Tryptophan	0.46	0.43
L-Threonine	0.17	0.17
L-Valine	0.07	0.04
Acidifying agent	0.10	0.10
Phytase	0.20	–
Analyzed composition and nutritional value ³		
CP, %	18.99	18.00
NDF, %	10.62	13.11
Ash, %	7.02	5.44
NE, MJ/kg	10.63	9.67
ME, MJ/kg	13.92	12.99

¹Piglets were fed the prestarter diet from d 1 (weaning) to 15 and the starter diet from d 16 to 28.

²Supplied per kilogram of diet (as-fed basis): vitamin A, 10,000 IU; vitamin D₃, 2,000 IU; vitamin E, 20 mg; vitamin K₃, 2 mg; thiamine, 2 mg; riboflavin, 5 mg; niacin, 20 mg; pantothenic acid, 10 mg; pyridoxine, 5 mg; biotin, 0.2 mg; folic acid, 1 mg; vitamin B12, 0.03 mg; choline chloride, 600 mg; ascorbic acid, 40 mg; Fe, 100 mg; Cu, 20 mg; Zn, 100 mg; Mn, 40 mg; I, 0.6 mg; Se, 0.3 mg; and Co, 1 mg.

³Information provided by COOPERL Arc Atlantique (Plestan, France).

weighed on d 28 at 0930 h before the daily feed provision. Because of experimental limitations, we were not able to weigh the animals on the weaning day (d 1). Nevertheless, we considered the weight value measured at d 0 as the initial weight at weaning (d 1) because weaning is a stressful event during which weight gain is almost insignificant. Average daily feed intake (g/d), ADG (g/d), and G:F were calculated for the whole experimental period (d 1 to 28).

Double-Choice Feeding Tests. On d 16 (i.e., the day of feed transition), 23 (i.e., 7 d after feed transition), and 26 (i.e., 10 d after feed transition), the animals were subjected to 2 consecutive double-choice feeding tests: a 1-h double-choice test from 1000 to 1100 h and a 22-h double-choice feeding test from 1100 to 0900 h the next day. These tests were performed to investigate the pigs' preferences during a short period and a longer period of exposure to the diets between the control starter diet (CON starter diet) and the

starter diet supplemented with the same feed additive (FA) that they were familiarized with in the prestarter diet (FA1, FA2, or FA3 starter diets for the FA1, FA2, and FA3 treatments, respectively).

On the day of the tests, the daily refusals of the day before were weighed at 0900 h before the pigs were consecutively subjected to the 1- and 22-h double-choice tests. For each test, the 2 starter diets (FA vs. CON) were distributed in equal quantities in each part of the 2-part feeder. Left and right positions of the diets in the feeder were counterbalanced across animals and test days to avoid any laterality bias. During the 1-h double-choice tests, feeds were distributed once at 1000 h, and during the 22-h double-choice tests, feeds were distributed twice a day at 1100 and 1600 h. The refusals were weighed at the end of each test. As for the CON treatment, 2 rations of the CON starter diet were distributed in equal amount in each part of the 2-part feeder.

Statistical Analysis

Statistical analyses were performed with the R 2.14.1 software (The R Foundation for Statistical Computing, Vienna, Austria). All the data were checked for normal distribution and homogeneity of variance using Shapiro-Wilk normality test and Bartlett test of homogeneity of variances, respectively. Performance data (ADG, ADFI, G:F, and initial and final BW) were compared between treatments using 1-way ANOVA. For each treatment, intake of the FA starter diet was compared with intake of the CON starter diet by paired Student's *t* tests to investigate feed preferences during the 1- and 22-h double-choice tests. All data are reported as means ± SEM. Feed preferences were also expressed in percentage and calculated as the intake of FA diet relative to total intake. The level of significance for all analyses was set as $P \leq 0.05$ and tendencies were considered at $0.05 < P \leq 0.10$.

RESULTS

Feed Intake and Growth Performance

Table 2 presents the effects of the feed additives on BW, growth performance, and feed intake during the whole experimental period. No difference in initial and final BW was found between the treatments, and no effect of the treatment was found on ADFI, ADG, or G:F.

Feed Preferences During One-Hour and 22-Hour Double-Choice Tests

During the 1-h preference tests performed 7 d after feed transition (d 23), the FA1 diet was consumed significantly more than the CON diet (78% of total intake; $P < 0.01$; Fig. 1). For the FA2 treatment, the animals consumed the

Table 2. Effects of diet supplementation with 3 feed additives (FA1, FA2, FA3, and CON¹) from weaning on performance of piglets during the early postweaning period (d 1 to 28)²

Days	Treatments				P-value ³
	FA1	FA2	FA3	CON	
BW, kg					
Initial BW (d 1)	8.33 ± 0.22	8.33 ± 0.34	8.33 ± 0.24	8.33 ± 0.41	1.000
Final BW (d 28)	19.67 ± 0.67	20.52 ± 0.82	20.43 ± 0.70	20.29 ± 0.96	0.873
ADG, g/d	405 ± 19	436 ± 22	432 ± 20	427 ± 27	0.763
ADFI, g/d ⁴	509 ± 29	538 ± 29	542 ± 22	556 ± 29	0.675
G:F	0.80 ± 0.03	0.81 ± 0.02	0.80 ± 0.02	0.77 ± 0.03	0.577

¹ FA1, FA2, FA3: Feed additives 1, 2 and 3; CON: Control.

² Pigs per treatment: $n = 8$. The feed additives were added in a standard prestarter diet from d 1 (weaning) to 15 and in a standard starter diet from d 16 to 28.

³ One-way ANOVA among treatments.

⁴ Total feed intake was not assessed on double-choice test days (d 16, 23, and 26). Consequently, ADFI was averaged on a 23 d period.

FA2 diet significantly more than the CON diet during the 22-h preference tests on d 16 (67% of total intake; $P < 0.05$; Fig. 2) and 26 (62% of total intake; $P < 0.01$). For the FA3 treatment, 10 d after feed transition (d 26), the FA3 diet was consumed significantly more than the CON diet during the 1-h preference tests (69% of total intake; $P < 0.05$), and the piglets tended to prefer the FA3 diet to the CON diet during the 22-h preference tests (60% of total intake; $P = 0.086$). No other significant difference was found.

DISCUSSION

According to our data, feed supplementation with FA1, FA2, and FA3 (in a prestarter diet for the first 15 d after weaning and in a starter diet from d 16 to 28) did not improve daily feed intake or growth performance during the first 28 d postweaning. When given the choice between the FA starter diet and the starter diet with no additive (CON) during 22 h, the pigs fed the FA2 treatment significantly preferred the FA2 diet the day of feed transition and 10 d later. For the FA3 treatment, the pigs preferred the FA3 diet to the CON diet 10 d after feed transition during both the 1- and 22-h tests, but no preference was found the day of feed transition and 7 d later. Seven days after feed transition, the piglets fed the FA1 treatment preferred the FA1 diet to the CON diet but only during the 1-h test.

That the FA2 unfamiliar starter diet was preferred to the standard starter diet with no additive on the day of feed transition suggests that the FA2 has the ability to mask the change of feed and would be efficient to reduce the negative effect of feed neophobia and maintain feed intake during a sudden feed transition. Certain flavors and sensory additives have the ability to mask the negative properties of unpalatable ingredients, which results in increased feed intake and preferences for the flavoring diets in pigs (Baidoo et al., 1986; Tedò et al., 2008; Sulabo et al., 2010; Michiels et al., 2012). Roura et al. (2007) also demonstrated the ability of certain aroma to mask the change of feed during a sudden feed transition. In pig

production systems, feed transitions are stressful periods during which the feeding activity of piglets is strongly disrupted due to unfamiliar feeding conditions (Forbes, 2007). Feed neophobia is frequently encountered during those periods and may result in decreased voluntary feed intake and impaired growth, until such time as the piglets fully accept their novel feeding and environmental conditions (Campbell, 1976; Dong and Pluske, 2007).

Recent findings showed that pigs have a large number of functional olfactory receptor genes compared with other mammal species, which tends to confirm that pigs have highly developed olfactory capacities (Groenen et al., 2012). The FA2 has a strong aroma of orange (*Citrus sinensis*) that was detectable in the feed by human nose—at least at the dose tested in the current study—while the aromatic potentials of the FA1 and FA3 were subtler. The aroma of the feed is the first stimulus that is perceived by the animals when exposed to the diet—the taste of the feed being only perceived once the animal has begun to consume the feed (Frederick and van Heugten, 2002). This may explain why the pigs preferred the FA2 unfamiliar starter diet from the first exposure the day of feed transition but did not prefer the FA1 and FA3 starter diets. Several studies in humans and rats showed that the aroma of orange essential oil reduced anxiety in stressful conditions (Lehrner et al., 2000, 2005; Faturi et al., 2010), which indicates that the beneficial impact of the FA2 the day of feed transition might be related to the anxiolytic properties of *Citrus sinensis*. Altogether, these findings suggest that aroma is of prime interest for the formulation of feed additives for pig production systems.

Although no preference was found the day of feed transition and 7 d later, the FA3 starter diet was preferred to the standard starter diet 10 d after feed transition. This finding suggests that the FA3 can significantly improve diet palatability and acceptance but only after a certain period of exposure. The FA3 is mainly composed of extracts of hot-flavored spices. In humans, Tepper et al. (2003) reported that hedonic responses to spices were subjected to a great

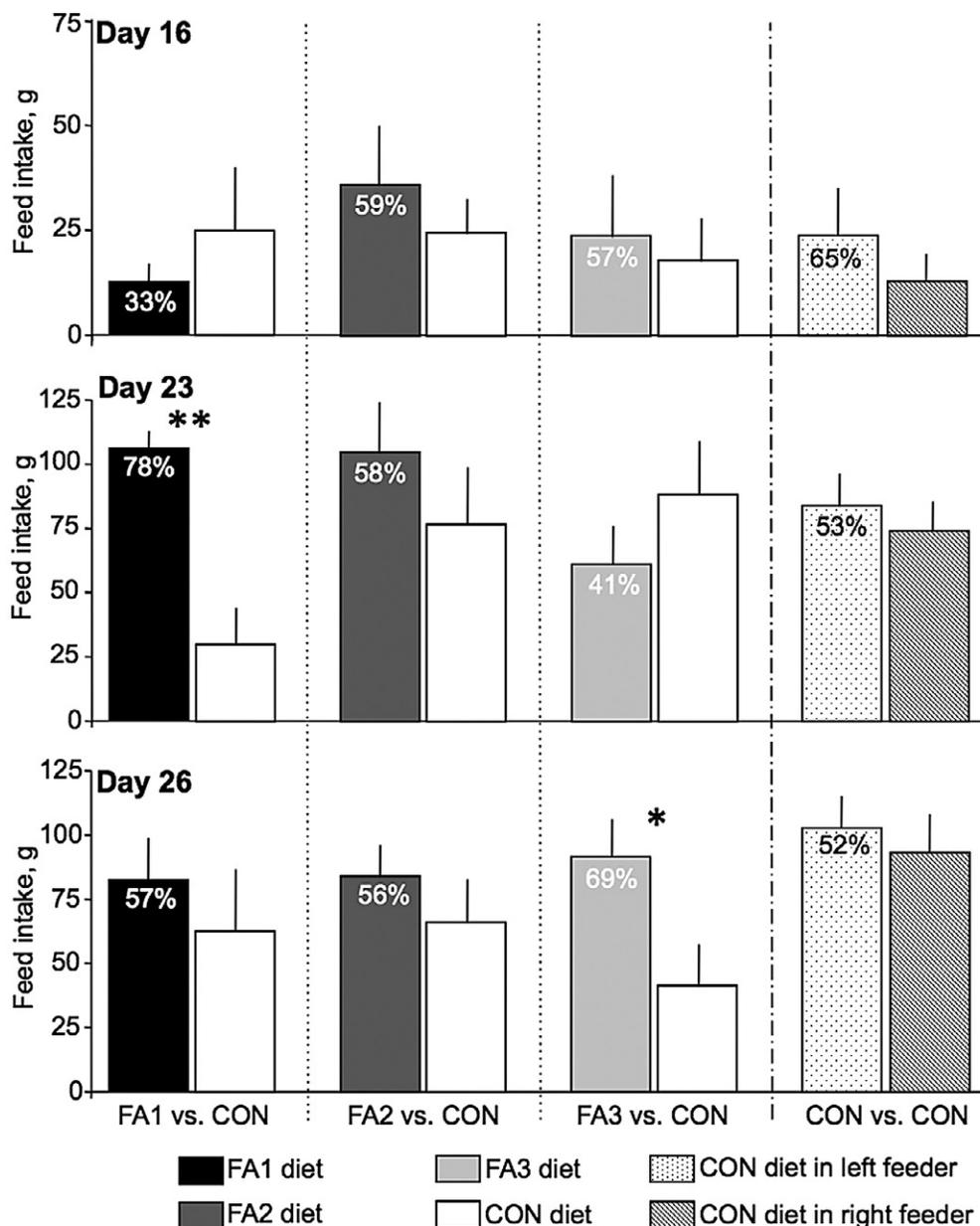


Figure 1. Feed intake (g) during the 1-h double-choice feeding tests for the FA1, FA2, FA3, and CON treatments. FA1, FA2, FA3: Feed additives 1, 2 and 3; CON: Control. During 1 h, the animals of the FA1, FA2, and FA3 treatments had the choice between the feed additives starter diet corresponding to their treatment and the CON starter diet. As for piglets fed the CON treatment, 2 rations of the CON starter diet were distributed in the left and right parts of the feeder. Three tests were done on d 16, 23, and 26. Data are presented with means and standard errors. Percentages in bars indicate diet intake relative to total intake. Asterisks indicate significant differences in feed intake within tests: * $P < 0.05$ and ** $P < 0.01$.

interindividual variability, and Ludy and Mattes (2012) argued that this great variability depends more on experience with spicy foods than on physiological and/or personality differences. Altogether, these findings suggest that, initially, the piglets perceived the palatability of the spicy FA3 very differently from one another, resulting in a lack of significant preferences the day of feed change. Afterward, while the animals were repetitively exposed to the additive, the perception of its palatability became more homogenous through familiarization/habituation processes—it is generally accepted that repeated exposure to the taste of a food

can increase intake and liking for it (for review in humans, see Wardle and Cooke, 2008). Further investigation is needed to determine whether a longer period of exposure to the FA3 (e.g., through maternal diet) would promote the emergence of more pronounced preference.

While the FA2, and to a lesser extent the FA3, appeared to have some beneficial effects on feed palatability/preferences, we did not manage to highlight any significant positive effect of the FA1 on feed preference or feed intake, except 7 d after feed transition but only during the 1-h test, which is not representative

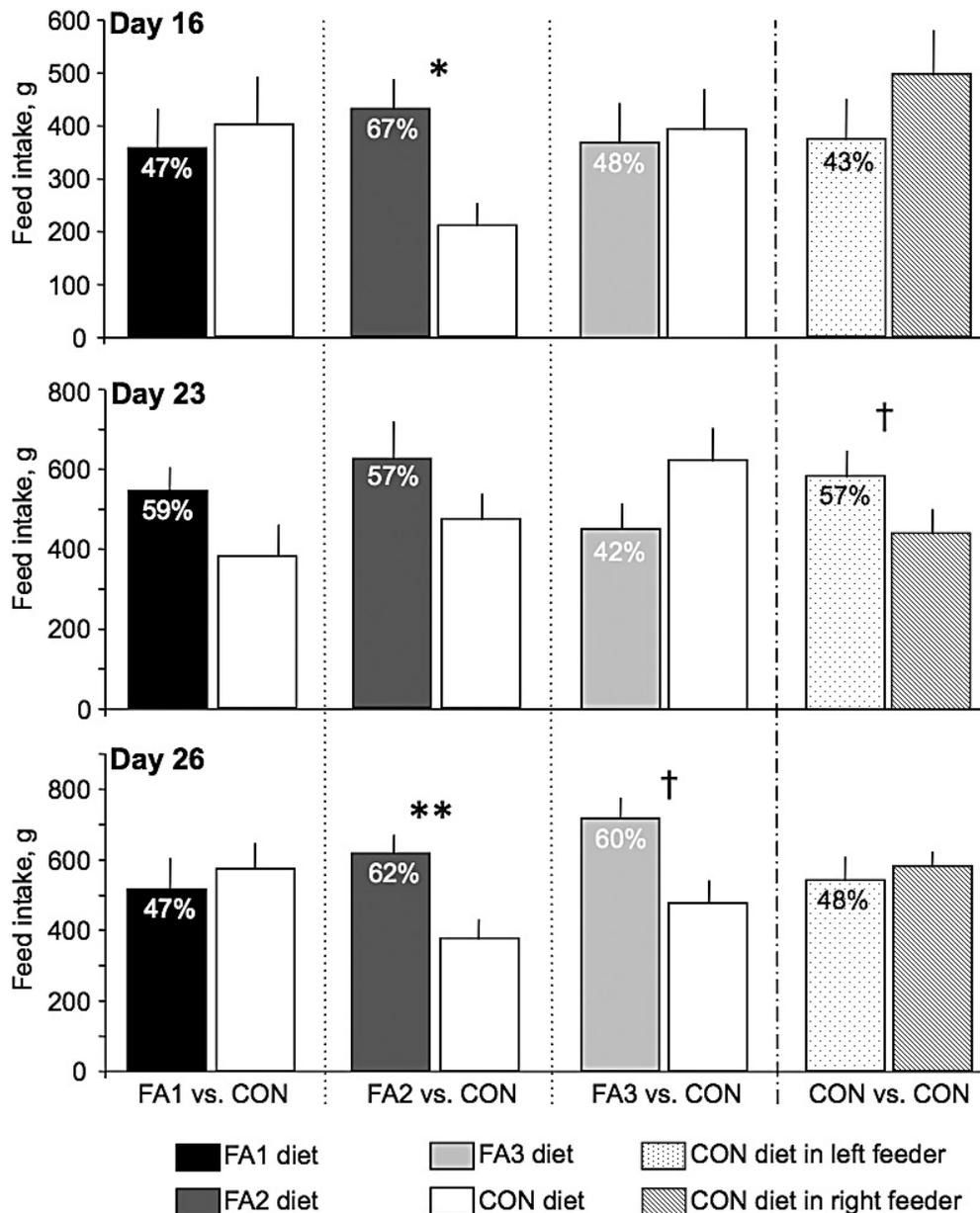


Figure 2. Feed intake (g) during the 22-h double-choice feeding tests for the FA1, FA2, FA3, and CON treatments. FA1, FA2, FA3: Feed additives 1, 2 and 3; CON: Control. During 22 h, the animals of the FA1, FA2, and FA3 treatments had the choice between the feed additives starter diet corresponding to their treatment and the CON starter diet. As for piglets fed the CON treatment, 2 rations of the CON starter diet were distributed in the left and right parts of the feeder. Three tests were done on d 16, 23, and 26. Data are presented with means and standard errors. Percentages in bars indicate diet intake relative to total intake. The symbols indicate significant differences in feed intake within tests: † $0.10 < P < 0.05$, * $P < 0.05$, and ** $P < 0.01$.

of preferences across the day. Yet such positive effects were expected given that the FA1 contained an extract of *Stevia rebaudiana*, with a minimum of 90% steviol glycosides (i.e., stevioside), which are the glycosides responsible for the sweet taste of stevia. Sweet taste is very attractive for pigs (Baldwin, 1976; Glaser et al., 2000; Nofre et al., 2002) and some sensory additives based on sweeteners are effective to increase feed palatability (Wahlstrom et al., 1974; McLaughlin et al., 1983; Michiels et al., 2012). According to electrophysiological studies, however, pigs are less sensible to steviol glyco-

sides than humans (Hellekant and Danilova, 1999). Yet it is worth noting that the FA1 is not a sweetener per se and also contained extracts of high-saponin plants. Saponins have been suggested to reduce diet palatability in pigs (Thacker and Haq, 2008; Carlson et al., 2012), which might explain the lack of consistent preference for the FA1 diet after feed transition in the current study.

Although the 3 feed additives tested in the present study seemed to have transient effects on feed preferences and palatability, they had no beneficial effect on growth performance and feed intake during the early

postweaning period. These findings corroborate previous studies that suggested that the effects of feed additives/flavors on growth and/or daily feed intake in a situation in which a unique feed was provided might be independent from palatability and preference during double-choice feeding tests (Wahlstrom et al., 1974; Yang et al., 1997; Seabolt et al., 2010; Clouard et al., 2012). Although Solà-Oriol et al. (2009) reported that double-choice feeding tests are an efficient strategy to compare the palatability of a feed supplemented with a flavor and the same feed with no additional flavor, some inconsistencies have been found between the preferences exhibited during double-choice feeding tests and in a situation in which no choice was given (Wahlstrom et al., 1974; Ermer et al., 1994). Consequently, preferences during double-choice feeding tests should not necessarily be extrapolated to preferences in a situation where a unique feed is provided (Forbes, 2007) and do not necessarily predict performance improvements.

Some studies also investigated the effects of phyto-genic feed additives composed of extracts of stevia, high-saponin plants, orange, or hot-flavored spices on piglets' growth performance and feed intake and mostly corroborate our results. No positive effect of high-saponin additives (Ilsley et al., 2005; Carlson et al., 2012) and only limited effects of stevia (Munro et al., 2000) have been found on ADFI, growth, and G:F in piglets. Some studies reported beneficial effects of a feed additive containing hot-flavored spices (e.g., black pepper, curcuma) on ADG, ADFI, and G:F in weaning but not growing piglets (Yan et al., 2011, 2012). Finally, Yamaguchi et al. (2005) found no positive effect of diet supplementation with dried orange pulp on ADG and back fat thickness of growing pigs.

Several factors may affect the efficiency of sensory feed additives to improve growth performance, feed intake, and feed palatability and may explain the lack of significant results of our study. First, in the present study, it is likely that the small number of animals ($n = 8$) prevented us from finding significant effects on feed intake and piglets' performance. As proposed by Sulabo et al. (2010), it is likely that a great individual variation in palatability perception might also be responsible for the lack of systematic preferences. We assume that repeating the experiment on a larger number of animals would enable us to tackle this issue. Second, individual characteristics, such as age or sex, may greatly influence the effects of feed additives on pigs' performance and feed intake (e.g., growing vs. finishing pigs; Thacker and Haq, 2009; Yan et al., 2011, 2012). Third, the period of exposure to the feed additive may also affect its impact on piglets' performance, and exposure to the additives from weaning might have been insufficient to see appreciable effects on growth and feed intake (Sulabo et al., 2010). Exposing

the piglets to the feed additives through maternal milk during the suckling period by adding the additive directly in the diet of lactating sows might enable to improve growth performance and intake during the early growing period (Ilsley et al., 2003; Matysiak et al., 2012). Finally, the inclusion rate of the additive in the feed is of primary importance for the improvement of feed intake/preferences in pigs (Jugl-Chizzola et al., 2006; Clouard et al., 2012; Michiels et al., 2012), which suggests that the effects of FA1, FA2, and FA3 could have been more pronounced if tested at different inclusion rates.

In conclusion, feed supplementation with FA1, FA2, and FA3 from weaning did not induce beneficial effects on feed intake and growth performance during the first 28 d postweaning. Interestingly, feed supplementation with FA2 increased the palatability and acceptance of the unfamiliar starter diet the day of feed transition, while FA1 and FA3 were only preferred after a few days of exposure to the starter diet. These differences suggest that FA2 has the ability to mask the change of feed during a sudden feed transition, while the positive effects of FA3 on feed palatability depend more on long-term familiarization processes. The intrinsic functional characteristics of the additives that are responsible for these effects remain unknown and need further investigation.

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