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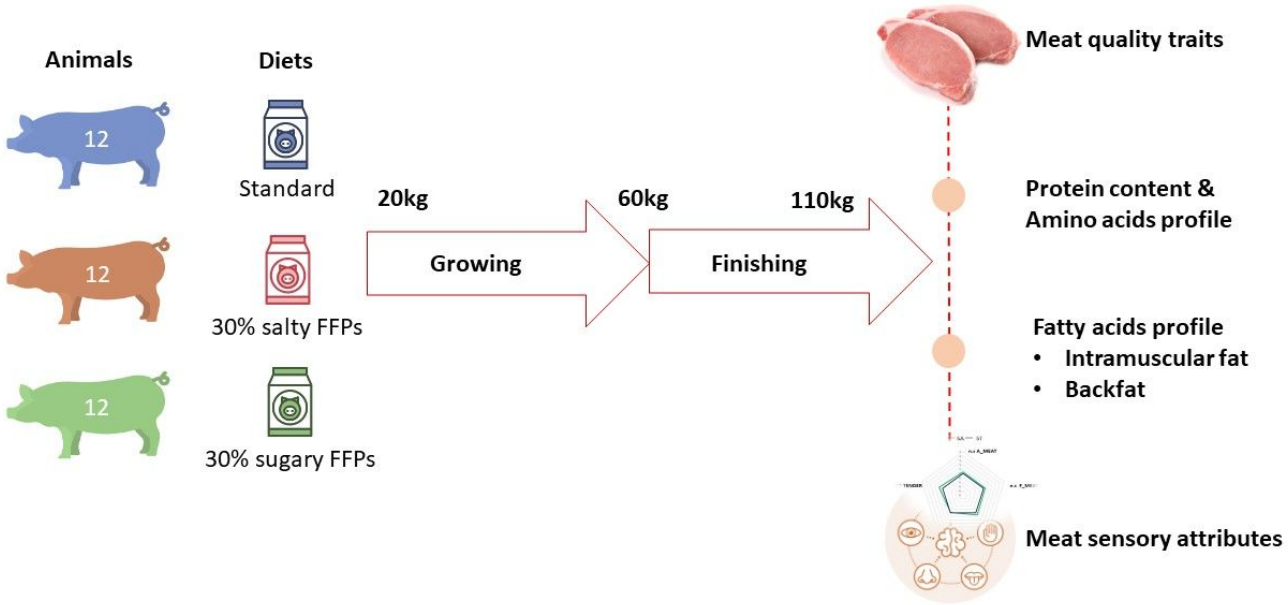
Graphical abstract



Sustainable Pig Diets: Partial Grain Replacement with Former Food Products and its impact on Meat Quality

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Running title

Sustainable Impact of Sweet and Salty FFPs on Pig Meat

Lay summary

Pigs are ideal species to convert food losses, also named Former Food Products (**FFPs**), into animal proteins. The present study investigated the impact of incorporating sugary and salty FFPs into the diets of growing and finishing pigs on meat quality and its sensory characteristics. Our study showed that, while technological meat quality remained largely unaffected, the dietary treatments led to slight alterations of meat and backfat fatty acids profile. Moreover, a panel test for sensory analyses revealed that loins from both the sugary and salty ingredients-fed pigs were perceived as sweeter, and loins from pigs fed salty ingredients were noted for increased tenderness, intense pork aroma, and flavour. Overall, FFPs inclusion into pig diets had no detrimental effects on technological or nutritional aspects of the meat, confirming their potential use as alternative animal feed.

Teaser text

- Reintroducing food losses, also known as former food products into pigs' diets contributes to the sustainability of livestock production
- Former food products as alternative feed ingredients do not compromise technological and nutritional pork quality or consumer perception.

Abstract

This study investigated the effects of salty and sugary Former Foodstuff Products (FFPs) on the quality traits and meat composition of 36 male castrated pigs (Swiss Large White breed) as well as sensory characteristics of the loins. The animals were fed three different diets for both the growing (G) and finishing (F) phases: (1) a standard diet (ST), 0% FFPs; (2) a diet with 30% of sugary FFPs (e.g., chocolate, biscuits, cakes) as a replacement for traditional ingredients (SU); and (3) a diet with 30% of salty FFPs (e.g., bread, pasta, breadsticks) as a

replacement for traditional ingredients (SA). For a comprehensive assessment of meat quality, protein and fat content in the LD were analysed. AA and FA profile were determined both in the LD and backfat. Meat quality traits such as pH and temperature, thawing, cooking and drip losses and shear force have been evaluated. Then, pork loins have been assessed for sensory attributes by a trained sensory panel. The SA diet decreased 20:5 n-3 levels ($P < 0.001$) in the muscle and 22:5 n-3 levels ($P < 0.05$) in both muscle and backfat but increased ($P < 0.05$) the ratio of mono-unsaturated to saturated fatty acids compared to the ST group. Both the SU and SA diets elevated ($P < 0.001$) the n-6:n-3 fatty acids ratio compared to the ST diet. Dietary treatments did not affect other meat quality traits. Regarding sensory attributes, the loin from pigs fed with SU and SA diets were sweeter ($P < 0.001$). Loins of SA pigs were more tender ($P < 0.001$), had a more intense pork aroma ($P < 0.001$) and had more flavor ($P < 0.01$) compared to ST loins. Overall, the use of FFPs affected the fatty acid profile of pork while improving the sensory quality of the loins, with no negative effects observed on the technological and nutritional quality of the meat.

Keywords

Former food products, meat quality, sustainable diets, sensory properties

List of abbreviations

a* redness

b* yellowness

C* saturation

CP Crude protein

EAA essential amino acids

FFP Former foodstuff products

H* hue angle

IMF intramuscular fat

L* lightness

LD *longissimus dorsii*

MUFA monounsaturated fatty acid

NEAA non-essential amino acids

PUFA polyunsaturated fatty acids

SCD Stearoyl CoA desaturases

SFA saturated fatty acid

WBSF Warner–Bratzler Shear Force

Introduction

To manufacture feed, a variety of ingredients are available, yet it's crucial to acknowledge that feed production carries an environmental footprint. Therefore, there's a pressing need to curtail the consumption of natural resources by enhancing their reutilization and adopting "circular" feed sources. In this context, ex-food, also known as Former Food Products (FFPs), emerges as a compelling solution. FFPs offer a means to transform losses from the food industry into ingredients for the feed sector, thereby ensuring the retention of nutrients within the food chain. This approach not only mitigates waste generation but also contributes to sustainability efforts within the agricultural and food industries. FFPs are food surplus originating from the confectionery and bakery food industries, comprise of ultra-processed food rejected for human consumption due to errors in the colour, shape, flavour or labelling of the product, logistical problems, or damaged packaging. These FFPs encompass salty foodstuffs, such as pasta, bread, and salty snacks, and sugary treats, such as cocoa-based products, candies, biscuits, and cereal bars (Pinotti et al., 2021). In general, FFPs consist of a blend of the above-mentioned sources

of salty and sugary food, supplied by different manufactures. The mixture of starting ingredients characterized by different nutritional composition can lead to a significant variability, however FFPs producers are able to predict the range of variation in the analysis between different sources of product and between the same source and different loads, owing to years of experience in the analysis of incoming products. Therefore, FFPs producers know how to predict the concentration of nutrients, obtaining a final product which is consistent and standardised (Tretola et al., 2019a). Distinct from food waste from restaurants, retail chains, or households, FFPs are considered microbiologically safe, and they undergo a different legislation compared to food waste (European Commission, 2018). In accordance with European Commission feed legislation, food waste can be intended for recycling (e.g., anaerobic digestion, composing) or can be recovered by incineration to produce energy, but it cannot be transformed into feed and re-enter the food chain (European Commission, 2018). Conversely, FFPs can be ‘’redistributed to people’’ and ‘’transformed into animal feed’’, since they are not considered as food scraps. Contrariwise, recycling and converting food waste into animal feed, after undergoing thermal processes, has been promoted in many non-European countries including Japan, South Korea, China, Taiwan and United States (Rajhe et al., 2021; James et al., 2022). The FFPs are a valid source of monosaccharides, lipids and highly digestible starch, since they are pre-cooked during the industrial processing. These characteristics suggest that FFPs are quite similar to common cereals, however they contain higher levels of fats, and they undergo to heat treatments, which make them suitable for young animals (Ottoboni et al., 2019). Tretola et al., 2019a and Luciano et al. (2021; 2022) reported that FFPs can be used as ingredients in piglet diets, showing no adverse effects on growth performance, diet digestibility, gut microbiota, or metabolic profile. These encouraging results showed the potential of utilising FFPs instead of cereals in swine diets to keep nutrients and reduce food losses within the agri-food chain and consequently mitigate the competition for

natural resources in the production of livestock feed and human food (Pinotti et al., 2023). Although food surplus represents a highly available biomass to be used as animal feed (about 5 million tonnes of FFPs produced/per year in the EU), only 3% of such biomass is actually reused and the remaining part is mainly destined to landfill or incineration, causing an environmental sustainability issue. This scenario is even more important at global level where if all non-usable food materials were used as feed for animals, these items may contribute up to 15% of total feed used for livestock (Sandström et al., 2022). Among livestock species, pigs, owing their omnivorous nature, can convert FFPs which are no more suitable for human consumption, into high quality animal proteins (Pinotti et al., 2023a). While sustainability gains precedence, maintaining meat quality remains paramount in the pork industry. Consumers demand high-quality pork products with excellent technological, nutritional, and sensory attributes (Liu et al., 2022; Pinotti et al., 2023b). Technological pork quality traits, nutritional value, and sensory attributes may be affected before and after slaughter, as well as at slaughter, by multiple interacting factors, such as feeding strategies (Lebret & Potokar, 2022). It is known that the amount of intramuscular fat (IMF) has a certain impact on the quality and sensory properties of pork (Hoa et al., 2021). For instance, the increase in the lipid content (highly marbled pork) positively influences the sensory attributes of meat such as texture, tenderness, flavor, and juiciness (Cannata et al., 2010). Conversely, a reduction of the lipid content is linked to a decreased water-holding capacity, which directly impacts colour and drip loss, and it may result in less tender pork chops (Saikia et al., 2024). Through nutritional manipulation is possible to modify the IMF levels. In swine production, various dietary strategies have been implemented to enhance IMF content. For example, it has been reported that dietary approaches aimed at increasing tissue fat saturation result in elevated IMF content and carcass fatness. Thus, lipid accumulation is positively associated to SFA concentration both in subcutaneous and IMF (Olivares et al., 2009). The dietary lipid sources consumed by pigs directly impact the

fatty acid composition of pork (Nieto and Ros, 2012). In pigs, the fatty acid profile of muscle and adipose tissue are easily adjusted by altering the ratio of fatty acids in their diet, particularly by feeding diets abundant in PUFAs, which are mainly found in grains and oleaginous seeds (Wood et al., 2008). The focus on the nature of fat sources in pigs' diets and the interest in modifying meat's fatty acid composition derives from the fact that fatty acid composition is crucial in defining meat quality since it determines differences in sensory attributes and in the nutritional value for human consumption (Nieto and Ros, 2012). Dietary fats and oils give the diet a high energy value, and their fatty acid pattern is reflected in those of animal products (Alonso et al., 2012). The lipid content of bakery and confectionery products is higher compared to traditional feed ingredients and their fatty acid profile contains a significant amount of SFAs especially from butter and partially hydrogenated vegetable oils. Based on the previous considerations, it is appropriate to evaluate the effect on meat lipid composition, when balanced diets supplemented with FFPs are fed to animals producing meat (Gutiérrez-Luna et al., 2022). This study aimed to evaluate the effects of partially replacing 30% of conventional grains with the same amount of sugary or salty FFPs in swine diets. This effort is part of a larger study using FFPs in growing finishing pigs. Here, we report how high dietary FFPs inclusion affects the meat composition and technological and sensory characteristics of pork chops. Our hypothesis was that the lipid composition of FFPs may adversely impair pork quality in terms of fat firmness and meat flavour compared to the control diet.

Material and methods

The experimental plan was compliant with the Swiss regulation of animal welfare. The Swiss Federal Committee for Animal Care and Use of Canton Fribourg in Switzerland authorized the experiment (authorisation code 2021-35-FR). The trial was carried out at the Agroscope Experimental Swine Research Centre in Posieux (Fribourg, Switzerland).

Animals and diets

The detailed rearing conditions, the performance traits, dietary treatments and the slaughter conditions of the barrows used to collect the meat and adipose tissue samples were previously described by Mazzoleni et al. (2023). Briefly, 36 castrated Swiss Large White male piglets from five litters were involved. Starting from the grower period, pigs weighed 22.38 ± 1.70 kg (mean ± SD) and were assigned within litters to one of the three dietary groups: standard (**ST**), salty (**SA**), and sugary (**SU**). Pigs were reared in a single-group pen in which they could access to three automated feeders with a single space (Mastleistungsprüfung MLP-RAP; Schauer Agrotronic AG, Sursee, Switzerland). The animals were fed individually using an ear tag with identification chip which allowed each pig to receive the assigned diet from the assigned computerized feeder. The SA-FFPs diet was formulated with salty products such as crackers, pasta, bread, breadsticks, whereas the SU-FFPs diet included sugary products such as chocolate, breakfast cereals, and cookies. The FFPs were divided between salty and sugary considering the total sugar content, expressed in sucrose. The chemical composition of the pure SA and SU FFPs used to formulate the experimental diets are reported in supplementary Table 1. The grower and finisher diets were formulated following the Swiss feeding recommendations for pigs (Agroscope, 2022) (Table 1). The standard grower diet (ST-G) and the standard finisher diet (ST-F) were formulated considering a reference BW of 40 kg and 80 kg, respectively. For the SA and SU grower (SA-G and SU-G, respectively) and finisher (SA-F and SU-F, respectively) diets, a portion of conventional ingredients such as cereals and fats included in the ST-G and ST-F diets were replaced by 30% salty and sugary FFPs. Comprehensive details regarding the ingredients and their respective inclusion levels utilized in formulating the diets can be found in the study conducted by Mazzoleni et al (2023). The pigs had ad libitum access to fresh water and to the grower and finisher diets from 20 kg to 60 kg BW and from 60 kg BW to slaughter, respectively. The grower and finisher diets were

formulated to be isoenergetic and isonitrogenous. All diets were prepared as pellets (< 70°C), and they included microbial phytase at 500 FTU/kg (0.16 digestible P/100 FTU). The fatty acid profiles of the dietary treatments differed (Table 1). The main difference in the saturated fatty acids (SFAs) was related to the 17:0 fatty acids, which were higher in the ST diet than in the SA and SU diets. Further, the monounsaturated fatty acid (MUFA) content of the diets differed, particularly regarding the 18:1n-9 content, for which the experimental diet had higher values than the ST diet. Finally, the polyunsaturated fatty acids (PUFA) content was higher in the ST diet than in the SA and SU diets (Table 1).

Slaughter procedure, sampling, meat trait measurements

Pigs were slaughtered at the Agroscope research slaughterhouse after fasting for 16 h (Bee et al., 2017) when they reached ~110 kg BW. The animals were stunned with CO2, after which they were exsanguinated, scalded, mechanically dehaired, and eviscerated.

The pH and temperature of the *longissimus dorsi* (LD) were monitored at 45 min, 3 h, and 24 h *post-mortem* using a Testo 205 pH metre (Testo, Mönchaltorf, Switzerland). Testo 205 are portable pH meters provided with pH and temperature probes and compensation is automatic. Moreover, the calibration was performed prior to each measurement series in conditions similar to those at which carcass was exposed. These measurements were performed at the 10th-rib level inside the intact left side of the carcass (Berard et al., 2008). At 24 h post-mortem, the LD from the left side of the carcass was cut between the 10th and 12th ribs to yield five 1.5 cm thick chops labelled from A to E. Subcutaneous fat was removed from chops.

Color and drip loss were measured at the end of the aging period on the chop A. After 20 min of blooming, L^* (lightness), a^* (redness), and b^* (yellowness) values were measured three times in each muscle section using a CM-700d Chroma meter (Illumina D65, light source C, observer 10°, aperture 8mm; Konica Minolta, Tokyo, Japan) in the CIE $L^*a^*b^*$ colour space.

Drip losses were measured as the proportions of purges generated during storage for 24 h at 2°C (Honikel, 1998). Prior the drip losses measurements, the samples were suspended as described in Bee et al., (2007). Chops were vacuum packaged, kept for 2 d at 4°C. Chops were leaved 3 days at 4°C, dry blotted, weighted and conditioned for drip loss (at the end of maturation) analysis. Forty-eight hours later, chops were dry blotted and weighted to determine purge loss. Then, bags were opened and chops were dry blotted, weighed, vacuum packaged and stored at -20°C until further analysis. Chops were allowed to thaw at 2 °C for a minimum of 24 h, then weighed to determine thaw loss on sections B and D. Subsequently, the LD chops were cooked on a 170°C pre-heated Indu-griddle SH/GR 3500 grill plate (Hugentobler, Schönbül, Switzerland) to an internal temperature of 69±2°C measured by an internal temperature probe associated to the cooking plate. Cooking loss was calculated by reweighing the cooked samples. Ten cores of 1.27 cm diameter per sample were obtained parallel to the fibre orientation with an electrical drill. The cores were obtained and always sheared in the same starting from the medial end of the chop. Finally, cooked samples from 10 cores of the LD chops (5 per chop) with a diameter of 1.27 cm each were cooled to ambient temperature. Shear force was determined by using a Texture Analyzer TA. HDplus (Stable Micro Systems, Godalming, England) equipped with a 2.5-mm thick Warner Bratzler shear blade (4mm/sec). Shear force was measured perpendicularly to the fibre direction. The maximum shear forces of 10 cores per chop (two chops per animal) were recorded and averaged per animal. Sections C and E were used for sensory analysis as described below.

Sample preparation for chemical analysis

Longissimus dorsii and backfat

All samples were freeze dried (Christ Delta 2-24, Kühner AG, Birsfelden, Switzerland) before analysis. After grinding with the Grindomix GM 200 (Retsch GmbH, Düsseldorf, Germany),

dry matter (DM) content of LD samples was analysed by heating at 105˚C for 3 h. Ash was then determined by incineration at 550°C until reaching a stable mass according to ISO 5984_2002 (prepASH 229, Precisa Gravimetrics AG, Dietikon, Switzerland). Backfat samples were grinded with a mixer and dried at 105°C for 3 h for determining the DM content (ISO 5984:2002; prepASH 229, Precisa Gravimetrics AG, Dietikon, Switzerland).

Chemical analysis

On feed samples, dry matter was determined gravimetrically after drying at 105°C for 3 hours. Ash content was determined after 3 hours at 550°C. The crude protein (CP) content (total N × 6.25) was analyzed with a LECO FP-2000 analyzer (Leco, Mönchengladbach, Germany) (International Organization for Standardization (ISO, 2008)). Feed samples were hydrolyzed in 10% (v/v) HCl for 1 hour to determine the dietary crude fat content. The hydrolysate was dried and extracted with petroleum ether using the Büchi SpeedExtractor E 916 (Büchi Labortechnik AG, Flawil, Switzerland). The fatty acid profiles of the feed were determined in lyophilized samples as described by Ampuero Kragten et al. (2014). Briefly, lipids were transmethylated for 3 h at 70 °C using 5% methanolic HCl as an acid reagent. The methyl esters were neutralized with a potassium carbonate solution and purified on silica gel. Fatty acid methyl esters were analyzed by gas chromatography (6850 series; Agilent Technologies AG, Basle, Switzerland) equipped with a flame ionization detector (detector temperature 250 °C). Nonadecanoic acid methyl ester (19:0) was used as internal standard.

Crude fibre content was obtained gravimetrically (ISO 6865:2000) by incinerating residual ash after acid and alkaline digestions with a fibre analyser (Fibretherm Gerhardt FT-12, C. Gerhardt GmbH & Co. KG, Königswinter, Germany)

Sodium content in the feed was analysed according to EN 15510:2008 by ICP-OES (ICP-OES 5800, Agilent Technologies, Switzerland) after microwave digestion. Samples were dissolved

in a glass tube (5 ml HNO3 65% + 3 ml H2O ASTM Class I) using a microwave digester (UltraClave, MLS GmbH, Leutkirch, Germany) at 235°C for 60 min (1000 W). Before the analysis, the samples were diluted with HNO3 2%.

On meat samples, protein content in the LD was analysed using the Dumas method (ISO 16634-1:2008) by a LECO TruMac CNS-928 (Leco, Mönchengladbach, Germany), which was calculated as total N × 6.25. Fat content was determined with petrol ether after acid hydrolysis (ISO 6492:1999) and used to calculate the IMF content. Fatty acids in the LD and backfat were determined by transmethylation/esterification under acid catalysis (5% HCl in MeOH) at 70°C for 3 h, as described by Ampuero Kragten et al. (2014). Briefly, depending on fat content, the samples were mixed with 0.25 to 2 ml of internal standard (C 19:0; nonadecanoic acid), 3 to 6 ml of HCl (5% in methanol), and between 0 and 1.75 ml of toluene. The reaction mix was neutralised using 6% K2CO3 and purified by solid-phase extraction. Fatty acids were determined using a gas chromatography instrument equipped with a flame ionisation detector and a SupelcowaxTM 10 polar column of 15 m × 0.1 mm, 0.1 μm of length (Agilent 6850, Agilent Technologies, Switzerland) (Ampuero Kragten et al., 2014).

Amino acids in the LD and backfat were measured according to ISO 13903:2005. Briefly, after oxidation, 24-h acid hydrolysis was performed with 6 M HCl, followed by derivatisation with AccQ-Tag Ultra reagent (Waters, Milford, MA, USA). Amino acid profile was determined by using ultra-high-performance liquid chromatography coupled with a UV detector (Vanquish Horizon, Thermo Scientific, Reinach, Switzerland).

Meat sensory analyses

Two chops from the left LD were thawed at 4°C for 24 h, sliced, and cooked for 10 min in a heating plate until the core temperature reached 69±2°C.

During cooking process pork, slices were rotated every minute and half to ensure even cooking. Then, once cooked, the slices were cut into 1 cm cubes. A total of 21 subjects (52% women; mean age: 26 ± 3 years) were recruited from employees and students of the Faculty of Agriculture and Food Sciences at the University of Milan (Italy). Only subjects who like, who regularly consume pork meat (at least once a week) and without food intolerances and allergies were selected. The study complied with the Declaration of Helsinki and was approved by the Ethics Committee of the University of Milan (protocol code: 92/22; date of approval: October 28, 2022). Signed informed consent was obtained from all the selected subjects. The participants attended nine training sessions at the Sensory and Consumer Science Laboratory (SCS Lab) of the Department of Food, Environmental and Nutritional Sciences of the University of Milan, designed according to ISO guidelines (ISO 8589, 2007).

A ‘‘difference from control’’ method was used (Meilgaard et al., 1999; Lawless & Heymann, 2010; Pagliarini, 2021). First, participants took part in six preliminary sessions to distinguish and define appropriate sensory attributes that characterise pork loins. After guided open discussions, redundant attributes were eliminated and the terms pork aroma, pork flavour, sweet taste, salty taste, and tenderness were selected during the sensory evaluation. During these sessions, the participants were instructed about the meaning of the sensory descriptors. Undoubtedly, sensory perception varies between individuals. However, the selection and training phases (Lawless et al., 2010), as well as the participation at several preliminary sessions to learn how to use the scale and their respective extremes allowed to include in the final panel only judges able to provide robust results. Their performance was monitored during the experimental sessions. Subsequently, 18 pork loin samples (six loin chops from each dietary treatment selected based on similar chemical composition to reduce the intra-variability among samples for each treatment were evaluated in three different sessions (30 min/session).

Each subject was first presented with the control sample (loin from pig fed with ST diet). After tasting the ST sample, subjects had to evaluate the loin samples from SA and SU diet (doing a comparison with ST sample; Meilgaard et al., 1999). The presentation order of SA and SU samples was randomised by judges. Intensity of each sensory attribute was rated on a linear structured scale with the control samples as central value (score 0), whereas the extremes were ‘‘much less intense than the control” (left side of the scale; score -5) and “much more intense than the control” (right side of the scale; score + 5). Each sample was presented to the participants as two cubes of meat provided in plastic plates labelled with three-digit codes in a serving portion. The judges were instructed to remove the cover, smell, and taste the samples. Data acquisition was performed with Fizzv2.31 software (Biosystèmes, Couternon, France).

Calculations and statistical analysis

Statistical analyses of meat quality traits and meat chemical composition were conducted using R software (Version 4.2.1). The results were analysed by ANOVA, and the model contained the dietary treatment (ST, SU, and SA) as a fixed effect and the litter of origin as a random effect. Only for the data about to LD colour parameters over time was a linear mixed-effects regression (Lme4) model (Bates et al., 2014) used, including the dietary treatment and the time (24 h vs. 72 h), and the two-way interaction was considered fixed effects and the animal as a random effect. For pairwise comparisons, the Sidak function was performed using a modified Tukey test for multiple comparisons of means. Means and pooled SEM were calculated with the *lsmeans* function from the *emmeans* package (Lenth & Lenth, 2018). The residuals of the linear mixed-effects models were checked for normality and homoscedasticity. Variables that did not follow a normal distribution (fatty acids in IMF and backfat) were subjected to logarithmic transformation before the data analysis. Values are presented as ls-means with their

348 standard errors. A P-value < 0.05 was considered significant while a P-value < 0.10 was
349 considered a tendence.
350 Sensory data were subjected to analysis of variance (ANOVA) considering treatments, judges,
351 sessions as fixed factors and sensory attributes ratings as dependent variables. The interaction
352 judges*sessions has been also evaluated to check judges' performance across sessions.
353 Differences among samples according to dietary treatment (SU vs. ST; SA vs. ST) were
354 evaluated through Dunnett test. A *P*-value < 0.05 was considered significant. The statistical
355 analysis was carried out using XLSTAT (Version 2019.2.2, Addinsoft, Boston, MA, USA).

356

357 **Results**

358 The fatty acid profiles of the dietary treatments differed (Table 1). The main difference in the
359 saturated fatty acids (SFAs) was related to the 17:0 fatty acids, which were higher in the ST
360 diet than in the SA and SU diets. Further, the monounsaturated fatty acid (MUFA) content of
361 the diets differed, particularly regarding the 18:1n-9 content, for which the experimental diet
362 had higher values than the ST diet. Finally, the polyunsaturated fatty acids (PUFA) content was
363 higher in the ST diet than in the SA and SU diets (Table 1).
364 *Protein content and amino acid composition of the longissimus thoracis*
365 The protein content and amino acid composition of the LD in pigs fed the ST, SA, or SU diets
366 are summarised in Table 2. Except for the tendency of a lower ($P = 0.08$) cysteine content in
367 the SA pigs compared to ST and SU pigs, the dietary treatment had no effect ($P > 0.05$) on the
368 protein, the essential (EAA) and non-essential (NEAA) amino acid content of the LD.
369 Concordantly, the ratios of EAA to NEEA, as well as the levels of flavour-enhancing amino
370 acids, were similar in the three treatment groups (Table 2).
371 *Meat quality, meat chemical composition, and fatty acids profile of the intramuscular fat*

The three dietary treatments had no effect on meat quality traits (Table 3). Similarly, the dietary treatments did not affect the colour parameters measured in the LD samples at 24 and 72 h post-mortem under vacuum refrigerated storage (Table 4), whereas storage time did ($P < 0.05$). The meat lightness (L^*), redness (a^*), yellowness (b^*), and saturation (C*) increased ($P \leq 0.01$) after 72 h, while hue angle (H*) decreased ($P < 0.05$).

Accordingly, both the SA and SU diets affected the fatty acid composition of intramuscular fat (Table 5). Regarding SFAs, only 17:0 was affected by the dietary treatment, with higher values in the ST ($P < 0.01$) than in the SA and SU groups. Total MUFA content was higher in the SA ($P < 0.01$) than in the ST and SU groups. This difference was mainly due to the higher content of 18:1n-9 fatty acid in the SA ($P < 0.01$) than the ST and SU groups, while both 17:1cis-10 and 18:1trans-11 levels were lower ($P < 0.01$) in the SA compared to the ST group with the SU group being intermediate. The content of PUFA in the IMF of the pigs fed the SA diet tended to be lower ($P = 0.08$) than in the ST pigs. In particular, the 18:3n-3, 20:5n-3, and 22:5n-3 levels were lower in the IMF of pigs fed the SA diet ($P < 0.01$) than those fed the ST diet. Compared to the ST, the SU showed a lower level of 18:3n-3 fatty acid ($P < 0.01$). The SA diet caused an increased MUFA/SFA ratio ($P = 0.02$) and a decreased sum of n-3 fatty acids ($P < 0.01$) compared to the ST and SU diets. Thus, the SA diet led to the highest value of n-6/n-3 ratio, while the lowest value was found in the IMF of pigs fed the ST diet.

Fatty acid composition of the backfat

The SA diets significantly decreased the total SFAs content in the backfat ($P < 0.01$) compared to both the ST and SU diets (Table 6). In particular, the content of 14:0, 15:0, 16:0, 17:0, and 18:0 was lower in the SA than in the ST group ($P < 0.01$), whereas the SU diet increased the abundance of the 12:0, 14:0, and 15:0 ($P < 0.01$) compared to the SA diet. The MUFA content

396 also differed between the three experimental diets ($P < 0.01$), with the lowest value in the ST
397 and the highest in the SA group.
398 With the exception of 20:1n-9, all MUFA analysed were significantly influenced by diet, as
399 shown in Table 6. The highest total MUFA value was found in the SA group, followed by SU
400 and ST. However, this difference was mainly due to the 18:1n-9 fatty acid, which was higher
401 in the SA group than in the ST and SU groups. By contrast, all other MUFA followed an
402 opposite trend, with a lower abundance in the SA group than in the ST group. The SU backfat
403 also differed from the SA in the MUFA profile, specifically for its higher levels of 14:1n-5 and
404 t18:1n-7 (Table 6).
405 Similar to the PUFA profile of the IMF, 18:3n-3, 20:3n-6 and 20:3n-3 were less abundant (P
406 < 0.01) in the SA compared to the ST and SU groups. The SA diet also increased ($P < 0.01$)
407 the MUFA/SFA ratio compared to the other dietary treatments. The sum of the n-3 fatty acids
408 and the n-6/n-3 fatty acids ratio were affected ($P < 0.01$) by both the SA and SU diets. In
409 particular, the SA group had the lowest levels of n-3 fatty acids, and the ST group had the
410 highest levels. Consequently, the SA group showed the highest value of n-6/n-3 ratio while the
411 ST diet had the lowest value.
412
413 *Meat sensory attributes: salty and sugary former food vs. standard diets*
414 ANOVA results depicted that the interaction 'judges * sessions' was not significant for any of
415 attributes considered (pork aroma: F = 0.89, $P = 0.67$; pork flavor: F = 1.02, $P = 0.43$; sweet
416 taste: F = 0.93, $P = 0.60$; salty taste: F = 0.87, $P = 0.69$; tenderness: F = 0.76, $P = 0.85$),
417 confirming judges' reliability throughout sessions. A significant treatment effect (Fig. 1) was
418 found for pork aroma (F = 12.83, $P < 0.001$), pork flavor (F = 4.54, $P < 0.01$), sweetness (F =
419 15.33, $P < 0.001$) and tenderness perception (F = 14.31, $P < 0.001$). No differences according
420 to dietary treatment has been highlighted for salty taste (F = 0.87, $P = 0.69$).

As reported in Table 7, the SA sample exhibited a significant greater intensity in terms of pork aroma and pork flavor compared to the ST sample. Sample obtained from pork feed by sugary formed food (SU) was perceived as significantly less intense than ST in term of pork aroma. Moreover, both SU and SA samples were perceived as sweeter compared to ST sample. As regard texture perception, SA sample was described as more tender than the ST sample.

Discussion

Meat quality traits and fatty acid composition

In this study, the replacement of 30% of common energy sources by salty or sugary FFPs in the grower and finisher periods did not affect pig meat quality traits, such as pH, temperature, water holding capacity, shear force, and colour. To our knowledge, this is the first study to evaluate the effects of FFPs on meat quality in pigs. Similar studies have been performed in pigs fed food waste products different from FFPs because of their nature, processing requirements, safety, and legislation status (Pinotti et al., 2021). For example, Kjos et al. (2000) investigated the effects of waste products such as food leftovers, food-processing plants and bakery waste, and dairy waste in diets for growing-finishing pigs on growth performance, carcass characteristics, and meat quality. The authors observed that increasing the levels of food waste products from 20% to 100% of the dietary net energy content reduced the fat firmness and lightness (L^* values) of both backfat and loin. Further, in Kjos et al.'s (2000) study, the proportion of SFAs decreased, while the PUFA level increased, but the sensory quality of the loin muscle was not affected. Biondi et al. (2020) observed that feeding pigs with tomato processing waste reduced the intramuscular fat, SFAs, and MUFA content and increased the n-6/n-3 fatty acid ratio in the intramuscular fat of pork. Kwak and Kang (2006) tested the effect of including 25 or 50% food waste and bakery by-products mixture (FWM) into a pig diet. They found that the experimental diets did not affect carcass characteristics (carcass weight, dressing percentage, backfat thickness and carcass grade), meat fatty acid

446 composition, meat quality (marbling score, pH, water holding capacity, drip loss, *L**, *a**, *b**
447 values, Warner-Bratzler shear force, cooking loss), and taste panel test (flavor, taste,
448 tenderness, juiciness, and overall acceptance) compared with feeding a corn-soy diet. However,
449 meat color was judged by the panel test as paler for 50% FWM fed animals than a corn-soy
450 diet fed animals. Meat color was the only limiting factor when FWM was fed to finishing pigs
451 Kwak and Kang (2006).
452 Our study showed different results for meat quality traits with FFPs compared to food waste.
453 In fact, including up to 30% FFPs had no detrimental effects on the colour and lightness of the
454 loin muscle. However, there might be interest in increasing the FFPs inclusion level from the
455 perspective of further reducing the use of grains and consequently the feed-food competition.
456 In the present study, we chose an inclusion of 30% of FFPs in pig's diet because, as reported
457 in studies testing the effects of the bakery meal on animals, a level of FFPs inclusion higher
458 than 30% could lead to detrimental effects on growth performance in pigs, as observed by
459 Luciano et al. (2022) in weaned pigs. To our knowledge, there are no data about the effects of
460 inclusion levels of FFPs higher than 30% in growing-finishing diets.
461 In the present study, the inclusion of 30% FFPs did not affect the accumulation of IMF in meat.
462 Despite controversial opinions, there is literature reporting that the presence of certain levels
463 of IMF contributes to a proper juiciness, tenderness, and flavour to the meat, and it is therefore
464 desirable for the consumer's acceptability (Lawrie & Ledward, 2014). The Swiss Large White
465 breed is known to have an IMF content of about 3%, which is considered optimal from a taste
466 point of view in Europe (Font-i-Furnols et al., 2012). In the present study IMF reached about
467 4% in all experimental groups, which is in line with values normally observed in pork of pigs
468 reared in our experimental station (Ewaoluwagbemiga et al., 2023). Although IMF content was
469 similar among diet groups in this study, dietary treatment did affect the IMF and backfat fatty
470 acid profile, with smaller effects on the IMF than on the backfat. For instance, the relative

content of SFA was unaffected in the IMF but decreased in the backfat of pigs fed the SA diet compared to pigs fed the ST and SU diets. It is known that the fatty acid profile of pork fat generally mirrors that of the diet (Wood et al., 2008). However, the majority of SFA is derived from de novo synthesis (Nakamura & Nara, 2004); thus, the lower SFA content in the backfat of the SA group cannot be completely explained by the correspondingly lower SFA content of the SA diet in both the growing and finishing phases compared to the SU and ST diets.

Stearoyl CoA desaturases (SCD), also known as delta-9 desaturase, are an essential component of de novo lipogenesis, as they catalyse the conversion of SFA to MUFA, which are key substrates for the formation of complex lipids, such as triglycerides and cholesterol esters (Flowers & Ntambi, 2009). The mRNA expression and activity of desaturase and elongase enzymes are influenced by numerous dietary components, including macronutrients (dietary fat, carbohydrates, and proteins), micronutrients (folate, vitamin B-12, and vitamin A), and polyphenols (resveratrol and isoflavones) (Gonzalez-Soto & Mutch, 2021). In particular, dietary PUFAs such as 18:2n–6 have been observed to decrease liver SCD activity, but SFA and MUFA do not (Gonzalez-Soto & Mutch, 2021). In our study, both the SA and SU diets resulted in a lower PUFA content, especially 18:2 n-6, than the ST diet. The low dietary PUFA content of the SU and SA diets did not suppress SCD activity, which desaturates SFA. This explains the lower SFA content and higher MUFA content in the backfat of SA pigs compared to ST pigs. However, the backfat of the SU pigs only had a higher MUFA content, while the amount of SFA was only numerically and not statistically lower than that of the ST pigs. We speculate that this discrepancy may be due to inter-animal variability, but this aspect merits further investigation.

This effect was observed only in backfat and not in IMF, probably because IMF is generally more unsaturated due to the greater amount of phospholipids (Yi et al., 2023). Compared to the ST and SU groups, the SA diet increased the relative MUFA content in both IMF and backfat.

In the IMF, this effect was due to the increased abundance of oleic acid (18:1n-9). This result is consistent with the higher content of 18:1n-9 in the SA diet compared to the other experimental diets. These results corroborate those of Martins et al. (2018) and Navarro et al. (2021), who showed that supplementing pig diets with oleic acid-rich oils increased the 18:1n-9 in pork fat. A higher oleic acid content and a high MUFA/PUFA ratio in the IMF have been associated with an improved release of pleasant aromatic notes from Maillard reactions in cooked pork due to the lipid-Maillard interaction (Navarro et al., 2021). The latter could explain, at least in part, the results observed in the sensory analysis, in which the SA diet improved the sensory attributes of the LD compared to the ST. Similarly, the SU diet also resulted in a higher MUFA content in the backfat compared to the ST diet. Further, the meat from the SU pigs was perceived as sweeter compared to those from ST pigs. The effects of the SA diet on omega-3 fatty acids resulted in a lower n-3 content and a higher n-6/n-3 fatty acid ratio in both IMF and backfat. Compared to the ST group, the SU group followed the same trend as the SA group.

The 18:3n-3 fatty acid, also known as alpha-linolenic acid, is an essential fatty acid and must be obtained in the diet. 18:3n-3 is also a precursor of the longer chain n-3 PUFA, 20:5n-3, and the 22:5n-3 fatty acids, also known as eicosapentaenoic acid and docosapentaenoic acid, respectively (Sinclair et al., 2002). Accordingly, the lower content of 18:3n-3 in the SA diet compared to the ST diet (Table 4) led to a reduced amount of the same fatty acid in the IMF and, consequently, lower levels of the derived fatty acids (20:5n-3 and 22:5n-3). Similarly, the lower amount of 18:3n-3 in the backfat of pigs fed the SA diet is probably due to its reduced intake from the diet. This also explains the lower abundance of the 20:3n-3 fatty acid in the backfat of SA pigs, as this fatty acid is known to be a “dead-end” elongation product of 18:3n-3 (Berger & German, 1990). The 20:3n-6 fatty acid (dihomo-gamma-linolenic acid) is a PUFA normally present in mammals at low levels, and its initial precursor is the 18:2n-6 fatty acid

(Mustonen & Nieminen, 2023). Again, the lower amount of the 20:3n-6 fatty acid in the SA pigs compared to the ST pigs is probably due to the lower content of the 18:2n-6 fatty acid in the SA diets. Taken together, these differences also explain the lower n-3 content and, consequently, the higher n-6/n-3 ratio in IMF and backfat of the SA-FFP-fed pigs compared to the ST. Although the high content of n-3 fatty acids is desirable in pork because of its potential beneficial effects on human health, increasing the n-3 content in pork could be problematic due to the off-odours and flavours resulting from the oxidation of the PUFA and consequently represent a challenge in food processing and storage (Wood et al., 2004).

Our results also showed that both 18:3n-3 and 18:2n-6 PUFA introduced by the diet were higher in the backfat than in the IMF, independent of the diet. This is in line with previous studies (Bee et al., 2002; Nguyen et al., 2003) and could be explained by the differences in the degree of incorporation of these PUFA into tissues. In particular, the intake of both 18:3n-3 and 18:2n-6 PUFA is probably higher than required, and part of these PUFA are stored in adipose tissue. The n-6/n-3 and PUFA/SFA ratios seem to play an important role, with several evidence indicating that diets with high n-3 PUFA content and low n-6/n-3 PUFA ratio could be more beneficial to human health (Dugan et al., 2015; O' Connell et al., 2017; Lee et al., 2018; Minelli et al., 2023). Specifically, values of n-6/n-3 ratio ranging from 1:1 to 5:1 positively affect lipid metabolism and inflammation, and are considered protective against degenerative pathologies; however, modern Western diets typically have values from 15:1 to 20:1 (Duan et al., 2014). FFPs are produced starting with ultra-processed foods commonly used in Western diets. Accordingly, both the SU and the SA experimental diets increased the n-6/n-3 ratio in both loin muscle and backfat compared to the ST diet, with the SA diet providing the highest value of the ratio. The PUFA content in pork is only dependent on the dietary PUFA content (Bee et al., 2002), therefore the higher n-6/n-3 ratios observed in the SA and SU groups can be attributed to the FFPs. It is known that the higher the dietary n-6/n-3 ratio, the higher

546 the metabolic health risk (Hibbeln et al., 2006). This effect of FFP-based diets on pork should
547 still be investigated in detail, although pork has a high n-6/n-3 PUFA ratio even when animals
548 are fed typical feed ingredients (Nong et al., 2020).
549 However, the meat and the backfat of the SA-fed pigs had a higher MUFA/SFA ratio, compared
550 to the pigs of the ST and SU dietary groups. The higher MUFA/SFA ratio in the SA diet reflects
551 the finisher diets' composition, with higher SFA and lower MUFA content in the ST and SU
552 finisher diets, compared to the SA. Based on previous findings and considering that the SA and
553 SU diets have 3% and 1% higher levels of n-6 than the control diet, the differences in IMF and
554 backfat observed between the dietary groups concerning the MUFA/SFA and n-6/n-3 ratio
555 were not negligible. However, it could be speculated that the level of IMF is too low for this
556 ratio to be harmful to human health.
557
558 *FFPs and their impacts on sensory attributes of pork*
559 Substituting common energy sources with sugary FFPs in the SU diet resulted in pork with
560 more perceived sweetness than pork from the ST-fed pigs. Similarly, including salty FFPs in
561 pig diets generated a dual effect on the sensory attributes of pork, leading to increased
562 tenderness and sweetness compared to pork from the ST-fed pigs. Moreover, salty FFPs in pig
563 diets led to an increase in both pork aroma and flavor. The fatty acid composition of the LD
564 muscle has been suggested to influence the eating quality of pork. The sweetness of the meat
565 is generally influenced by meat marbling, which consumers perceive as sweeter due to
566 enhanced flavour and liking (Ngapo et al., 2012). Moreover, free amino acids such as Gly, Ala,
567 Ser, Thr, Pro and Hyp and higher amounts of oleic acid-derived compounds are known to be
568 associated with the sweet flavour of pork (Hoa et al., 2021; López-Martínez, 2023). In the
569 present work, the dietary treatments did not affect the level of IMF accumulation and the
570 abundance of sweet flavour-related amino acids in the loins. However, the content of oleic acid

571 was significantly higher in the IMF of SA group compared to ST group. Although not
572 significant, oleic acid content was numerically higher also in the SU group when compared to
573 ST, which may have contributed to the sweeter perception. The IMF in pork has also been
574 found to positively influence meat juiciness and tenderness (Junior et al., 2024). However,
575 some studies did not find such a relationship, and the correlation between IMF and the sensory
576 quality of pork remains controversial (Ngapo et al., 2012). As reported in the literature, the
577 main determinants of meat tenderness beyond the IMF content are connective tissue and the
578 proteolysis of key muscle proteins, which minimises the loss of water-holding capacity
579 determining its tenderness (Van Laack et al., 2001). No difference in shear force values was
580 observed, therefore the effect of SA and SU diets on the proteolysis kinetics of the myofibrillar
581 structure was not considered in this study.
582 Despite the different fatty acid profile of the diets, meat quality and intramuscular fat
583 accumulation were similar between the three experimental groups. This lack of difference in
584 meat quality parameters despite different fatty acid compositions aligns with previous studies,
585 in which two diets differing in fatty acid composition did not lead to significant differences in
586 overall meat quality traits and flavour precursors, despite differences in lipid composition and
587 sensory attributes (Tikk et al., 2007). Similarly, previous studies (Bee et al., 2008; Tretola et
588 al., 2019b) have showed that feeding growing-finishing pigs with diets with different
589 supplementation levels of fatty acids did not influence the general meat qualitative traits.
590 According to our study, the IMF of the SA group showed a higher MUFA/SFA ratio than that
591 of the ST group. In this regard, we speculated that the SFA content, particularly 18:0, 18:2, and
592 the MUFA/SFA ratio could affect fat consistency (Ospina-E et al., 2012). Contrary to
593 unsaturated FAs, SFA strongly influences the solid fat content of lipids, which expresses the
594 solid fraction amount of lipids at each temperature, because of their high melting points (Hugo
595 & Roodt, 2007). The literature reports that the higher content of several saturated fatty acids

(SFA) in the backfat of ST pigs compared to SA pigs is positively correlated with fat firmness (Wood et al., 2008). By including 30% SU and SA FFPs in pig diets, no negative impact on meat quality characteristics was observed. By contrast, the inclusion of FFPs altered the fatty acid profile of the meat and backfat, resulting in an increased n-6/n-3 fatty acid ratio.

The sweetness of the meat was found to increase with both the SU and SA-FFPs. However, the tenderness of the meat was only higher when pigs were fed SA-FFPs. Additionally, the perception of pork aroma and flavor was also more intense with the SA-FFPs.

The lack of detrimental effects on meat quality traits is a positive outcome for including 30% FFP levels in diets of growing finishing pigs.

Disclosure of potential conflicts of interest

The authors declare no conflicts of interest.

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M. Tretola: Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing & Visualisation. **S. Mazzoleni:** Investigation, Writing - Original Draft, Writing - Review & Editing & Visualisation. **P. Silacci:** Methodology, Investigation, Writing - Review & Editing & Formal analysis **S. Dubois:** Investigation & Formal analysis. **C. Proserpio:** Investigation, Formal analysis & Writing - Review & Editing. **E. Pagliarini:** Methodology, Investigation & Resources. **C.E.M. Bernardi:** Writing - Review & Editing. **L. Pinotti:** Funding acquisition, Supervision, Visualisation, Writing - Review & Editing. **G. Bee:** Funding acquisition, Resources, Project administration, Supervision, Methodology, Formal analysis & Writing - Review & Editing.

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Table 1. Diet composition and nutrient and digestible energy content (g/kg or MJ/kg on DM) of the unsupplemented standard growing (ST-G) and finishing (ST-F) diets and the growing and finishing diets supplemented with 30% salty (SA-G and SA-F) or sugary (SU-G and SU-F) former food products fed to growing-finishing pigs.

Items	Dietary treatments[1]					
	Growing diets			Finishing diets		
	ST-G	SA-G	SU-G	ST-F	SA-F	SU-F
Crude fat	52	53	61	45	53	59
Crude protein	173	174	176	152	151	153
Crude fibre	42	40	39	42	39	40
Sodium	1.3	3.7	1.5	1.7	3.2	1.7
Total ash	68	74	72	62	65	64
Fatty acids profile, g/100 g total fatty acids						
SFA	34.1	21.9	34.0	34.4	19.9	31.9
12:0	0.00	0.16	1.25	0.00	0.00	1.17
14:0	1.21	0.36	1.54	1.13	0.30	1.56
15:0	0.26	0.00	0.11	0.24	0.00	0.18
16:0	22.8	17.3	21.8	23.5	16.1	21.0
17:0	0.53	0.00	0.25	0.51	0.00	0.00
18:0	8.93	3.05	8.11	8.65	2.74	7.21
20:0	0.22	0.29	0.33	0.23	0.27	0.30
22:0	0.16	0.45	0.25	0.17	0.40	0.24
24:0	0.00	0.22	0.11	0.00	0.19	0.15
MUFA	34.3	48.7	38.9	31.1	50.1	39.9
16:1	1.57	0.28	0.67	1.45	0.28	0.66
18:1 trans-11	2.28	0.92	1.28	2.11	0.89	1.23
18:1 cis-9	29.2	47.1	36.4	26.3	48.5	37.3
20:1 n-9	0.50	0.37	0.34	0.49	0.37	0.34
PUFA	31.6	29.4	27.1	34.5	30.0	28.2
18:2 n-6	28.3	27.1	24.9	31.6	28.0	26.0
18:3 n-3	2.94	2.35	2.33	2.79	2.05	2.16
MUFA/SFA ration	1.01	2.22	1.14	0.91	2.52	1.25

Calculated						
Digestible phosphorus, g/kg DM	2.9	2.9	2.9	2.2	2.2	2.2
Digestible lysine, g/kg DM	8.3	8.3	8.3	6.2	6.2	6.2
DE, MJ/kg DM	13.7	13.7	13.7	13.7	13.7	13.7

868 Abbreviations: ST = standard diet; SA = salty former food diet; SU = sugary former food diet;
869 DE = digestible energy.
870 [1]All diets for the growing and finishing phases were formulated according to the energy and
871 nutrient requirements of pigs with a BW of 40 and 80 kg, respectively (Agroscope, 2022).
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874 **Table 2.** The amino acid composition of the longissimus thoracis muscle from pigs fed either
875 a basal grower-finisher diet or the basal diet with 30% salty (SA) or sugary (SU) former food
876 products.

	Dietary treatments[1]				
Items	ST	SA	SU	SEM	*P*-values
Total Protein	82.60	80.00	81.10	0.671	0.291
Essential amino acids (EAA)					
Arginine (Arg)	5.00	4.89	4.95	0.041	0.292
Histidine (His)	3.30	3.20	3.20	0.032	0.271
Isoleucine (Ile)	3.90	3.80	3.80	0.031	0.314
Leucine (Leu)	6.30	6.20	6.30	0.052	0.245
Lysine (Lys)	6.90	6.70	6.80	0.061	0.257
Methionine (Met)	2.20	2.10	2.10	0.021	0.236
Phenylalanine (Phe)	3.10	3.00	3.10	0.032	0.291
Threonine (Thr)	3.45	3.39	3.40	0.033	0.263
Valine (Val)	4.13	3.99	4.03	0.042	0.262
EAA[2]	38.80	37.50	37.90	0.301	0.264
Non-essential amino acids (NEAA)					
Alanine (Ala)	4.40	4.20	4.30	0.041	0.269
Asparagic acid (Asp)	7.39	7.14	7.30	0.072	0.293
Cysteine (Cys)	1.00	0.98	1.00	0.011	0.082
Glutamic acid (Glu)	12.20	11.80	11.90	0.112	0.344
Glycine (Gly)	3.40	3.30	3.30	0.032	0.244
Proline (Pro)	2.87	2.80	2.83	0.021	0.321
Serine (Ser)	2.88	2.78	2.81	0.020	0.212
Tyrosine (Tyr)	2.88	2.77	2.82	0.030	0.221
NEAA[3]	37.00	35.80	36.30	0.320	0.270
Total amino acids	75.80	73.30	74.20	0.601	0.267
EAA/NEAA	1.05	1.05	1.04	0.101	0.536

Flavour amino acids[4]	32.50	31.40	31.70	0.281	0.295

Data are expressed as % of the dry meat weight
Abbreviations: ST = standard diet; SA = salty former food diet; SU = sugary former food diet
[1]All diets for the growing and finishing phases were formulated according to the energy and nutrient requirements of pigs with a BW of 40 and 80 kg, respectively (Agroscope, 2022).
[2]EAA = Lys + Met + Thr + Val + Leu + Ile + Tyr + Phe + His + Arg.
[3]NEAA = Arg + His + Asp + Glu + Ala + Pro + Ser + Cys.
[4]Flavor amino acids = Glu + Asp + Ala + Arg + Gly.

887 **Table 3.** Meat quality traits from pigs fed either a basal grower-finisher diet or the basal diet
888 with 30% salty (SA) or sugary (SU) former food products.

	Dietary treatments[1]				
Items	ST	SA	SU	SEM	*P*-values
pH_{45min}	6.70	6.80	6.70	0.051	0.391
pH_{3h}	6.50	6.60	6.50	0.072	0.583
pH_{24h}	5.40	5.40	5.40	0.021	0.472
T_{45min}, °C	34.30	34.70	33.60	0.780	0.566
T_{3h}, °C	20.80	21.00	20.70	0.342	0.834
$T_{24\ h}$, °C	5.00	4.90	4.70	0.171	0.545
Thawing loss, %	6.00	5.40	5.70	0.311	0.413
Cooking loss, %	21.50	21.30	21.10	0.732	0.952
Drip, %	2.30	2.30	2.80	0.263	0.271
WBSF, N	51.10	47.70	48.90	2.351	0.583

889 Abbreviations: ST = standard diet; SA = salty former food diet; SU = sugary former food diet
890 [1]All diets for the growing and finishing phases were formulated according to the energy and
891 nutrient requirements of pigs with a BW of 40 and 80 kg, respectively (Agroscope, 2022).
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894 **Table 4.** Effect of a basal grower-finisher diet or the basal diet with 30% salty (SA) or sugary
895 (SU) former food products and storage time on porcine longissimus thoracis color.

	Dietary treatments[1]							*P*-values[2]		
	ST		SA		SU					
Time	24 h	72 h	24 h	72 h	24 h	72 h	SEM	D	T	D × T
*L**	56.1	58.5	56.3	59.8	56.5	59.4	0.63	0.775	<0.001	0.297
*a**	0.8	1.2	0.9	1.2	0.8	1.1	0.09	0.745	0.001	0.838
*b**	11.9	13.2	11.8	13.4	11.7	13.1	0.21	0.571	<0.001	0.561
C*	12.3	13.7	12.1	13.8	11.9	13.5	0.24	0.611	<0.001	0.681
H*	77.9	75.6	77.6	76.3	78.5	76.6	0.01	0.663	0.021	0.547

896 Abbreviations: ST = standard diet; SA = salty former food diet; SU = sugary former food diet;
897 [1]All diets for the growing and finishing phases were formulated according to the energy and
898 nutrient requirements of pigs with a BW of 40 and 80 kg, respectively (Agroscope, 2022).
899 [2]*P*-values for the effect of the dietary treatment (D), time of storage (T), and of the D × T
900 interaction.
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904 **Table 5.** Fatty acid profile (g/100 g total fatty acids) in the intramuscular fat from pigs fed
905 either a basal grower-finisher diet or the basal diet with 30% salty (SA) or sugary (SU)
906 former food products.

	Dietary treatments[1]				
Items	ST	SA	SU	SEM	P-values
Intramuscular fat, g/kg muscle	40.10	47.90	44.10	6.611	0.351
Fatty acid profile, g/100 g total fatty acids					
SFA	38.30	37.50	38.50	0.221	0.209
10:0	0.08	0.09	0.07	0.005	0.514
12:0	0.10	0.10	0.10	0.002	0.178
14:0	1.29	1.25	1.31	0.016	0.390
16:0	24.30	24.10	24.50	0.125	0.575
17:0	0.17[b]	0.14[a]	0.15[a]	0.003	<0.001
18:0	12.10	11.70	12.10	0.133	0.306
MUFA	53.00[a]	54.80[b]	53.40[a]	0.228	0.002
16:1n-7	3.38	3.10	3.21	0.075	0.320
16:1cis-3	0.30	0.32	0.30	0.008	0.584
17:1cis-10	0.24[b]	0.18[a]	0.19[a]	0.006	<0.001
18:1trans-11	4.25[b]	3.86[a]	3.99[ab]	0.054	0.008
18:1n-9	43.70[a]	46.50[b]	44.60[a]	0.251	<0.001
PUFA	8.75	7.65	8.11	0.203	0.081
18:2n-6	5.99	5.38	5.67	0.127	0.148
18:3n-6	0.06	0.05	0.04	0.003	0.067
20:3n-6	0.16	0.14	0.15	0.005	0.099
20:4n-6	1.12	0.95	1.02	0.047	0.353
20:2n-6	0.19	0.19	0.19	0.003	0.886
22:4n-6	0.15	0.14	0.14	0.004	0.380
18:3n-3	0.38[b]	0.30[a]	0.34[a]	0.008	<0.001
20:3n-3	0.07	0.05	0.06	0.002	0.056

20:5n-3	0.08[b]	0.05[a]	0.06[ab]	0.003	<0.001
22:5n-3	0.17[b]	0.11[a]	0.14[ab]	0.007	<0.001
MUFA/SFA ratio	1.39[a]	1.46[b]	1.39[a]	0.013	0.022
PUFA/SFA ratio	0.23	0.20	0.21	0.006	0.196
Sum of n-3 fatty acids[3]	0.71[b]	0.52[a]	0.60[b]	0.017	<0.001
Sum of n-6 fatty acids[2]	7.68	6.84	7.22	0.184	0.180
n-6/n-3 fatty acid ratio	10.80[a]	13.10[c]	12.00[b]	0.201	<0.001

907 Abbreviations: ST = standard diet; SA = salty former food diet; SU = sugary former food diet
908 [1]All diets for the growing and finishing phases were formulated according to the energy and
909 nutrient requirements of pigs with a BW of 40 and 80 kg, respectively (Agroscope, 2022).
910 [2]n-3 fatty acids = 18:3 (cis-9,12,15-octadecatrienoic acid), 20:3 (cis-11,14,17-eicosatrienoic
911 acid), 20:5 (cis-5,8,11,14,17-eicosapentaenoic acid), 22:5 (cis-7,10,13,16,19-
912 docosapentaenoic acid).
913 [3]n-6 fatty acids = 18:2 (cis-9,12-octadecadienoic acid), 18:3 (cis-6,9,12-octadecatrienoic acid),
914 20:2 (cis-11,14-eicosadienoic acid), 20:3 (cis-8,11,14-eicosatrienoic acid), 20:4 (cis-5,8,11,14-
915 Eicosadienoic acid), 22:4 (cis-7,10,13,16-docosatetraenoic acid).
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Table 6. Fatty acid profile (g/100 g total fatty acids) in the carcasses' backfat from pigs fed either a basal grower-finisher diet or the basal diet with 30% salty (SA) or sugary (SU) former food products.

	Dietary treatments[1]				
Item	ST	SA	SU	SEM	*P*-values
SFA	41.3[b]	38.1[a]	40.0[b]	0.33	<0.001
10:0	0.05	0.04	0.05	0.002	0.646
12:0	0.07[a]	0.07[a]	0.13[b]	0.005	<0.001
14:0	1.21[b]	1.07[a]	1.31[c]	0.021	<0.001
15:0	0.06[b]	0.04[a]	0.06[b]	0.002	0.001
16:0	24.2[b]	22.8[a]	23.4[a]	0.15	<0.001
17:0	0.35[b]	0.26[a]	0.31[ab]	0.102	0.001
18:0	15.1[b]	13.6[a]	14.5[ab]	0.23	0.015
20:0	0.23	0.22	0.23	0.004	0.707
MUFA	47.4[a]	50.8[c]	48.8[b]	0.31	<0.001
14:1n-5	0.02[b]	0.01[a]	0.02[b]	0.001	<0.001
16:1n-7	1.85[b]	1.39[a]	1.53[a]	0.051	<0.001
17:1n-10	0.35[b]	0.23[a]	0.28[a]	0.013	<0.001
t18:1n-7	2.75[c]	2.02[a]	2.24[b]	0.059	<0.001
18:1n-9	40.9[a]	45.8[c]	43.2[b]	0.38	<0.001
19:1n-9	0.08[b]	0.05[a]	0.07[ab]	0.004	0.034
20:1n-9	1.09	1.16	1.21	0.026	0.172
PUFA	11.2	11.0	11.1	0.10	0.830
18:2n-6	8.59	8.85	8.72	0.079	0.422
18:3n-6	0.02	0.01	0.01	0.001	0.495
20:2n-6	0.45	0.45	0.45	0.007	0.998
20:3n-6	0.062[b]	0.054[a]	0.059[ab]	0.0011	0.005
20:4n-6	0.16	0.16	0.15	0.003	0.117
22:4n-6	0.05	0.05	0.05	0.002	0.878

18:3n-3	0.76[c]	0.62[a]	0.69[b]	0.013	<0.001
20:3n-3	0.14[b]	0.11[a]	0.13[b]	0.003	<0.001
20:5n-3	0.01	0.01	0.01	0.002	0.462
22:5n-3	0.06	0.04	0.05	0.002	0.074
PUFA/SFA ratio	0.27	0.29	0.28	0.004	0.171
MUFA/SFA ratio	1.15[a]	1.33[b]	1.22[a]	0.017	<0.001
Sum of *n-3* fatty acids[2]	0.96[c]	0.78[a]	0.88[b]	0.017	<0.001
Sum of *n-6* fatty acids[3]	9.34	9.59	9.45	0.083	0.477
n-6/n-3 fatty acid ratio	9.72[a]	12.30[c]	10.73[b]	0.21	<0.001

Abbreviations: ST = standard diet; SA = salty former food diet; SU = sugary former food diet.
[1]All diets for the growing and finishing phases were formulated according to the energy and nutrient requirements of pigs with a BW of 40 and 80 kg, respectively (Agroscope, 2022).
[2]n-3 fatty acids = 18:3 (cis-9,12,15-Octadecatrienoic acid), 20:3 (cis-11,14,17-Eicosatrienoic acid), 20:5 (5Z,8Z,11Z,14Z,17Z-eicosa- 5,8,11,14,17-pentenoic acid), 22:5 (cis-7,10,13,16,19-docosapentaenoic acid).
[3]n-6 fatty acids = 18:2 (cis-9,12-octadecadienoic acid), 18:3 (cis,cis,cis-6,9,12-octadecatrienoic acid), 20:3 (cis-8,11,14-eicosatrienoic acid), 20:2 (cis-11,14-eicosadienoic acid), 20:4 (cis-5,8,11,14-eicosadienoic acid), 22:4 (cis-7,10,13,16-docosatetraenoic acid).

933 **Table 7.** Mean values of sensory attributes of pork from pigs fed basal diet with 30% salty
934 (SA) or sugary (SU) former food products compared to the reference pork from pigs fed basal
935 grower-finisher diet.

SENSORY ATTRIBUTES	TREATMENT	P	TREATMENT	P
	ST *vs* SA		ST *vs* SU	
Pork aroma	0.37	0.012	-0.34	0.031
Pork flavor	0.36	0.011	0.00	1
Sweet	0.60	<0.001	-0.46	<0.001
Salty	0.11	0.620	0.07	0.790
Tenderness	0.84	<0.001	-0.30	0.110

936 Abbreviations: ST = standard diet; SA = salty former food diet; SU = sugary former food diet.
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952 **Fig. 1.** Mean values of sensory attributes for samples derived from pigs fed the sugary (SU)
953 and salty (SA) diets compared to the samples derived from pigs fed standard diets (ST). n.s.
954 not significant; ** $P < 0.01$; *** $P < 0.001$.
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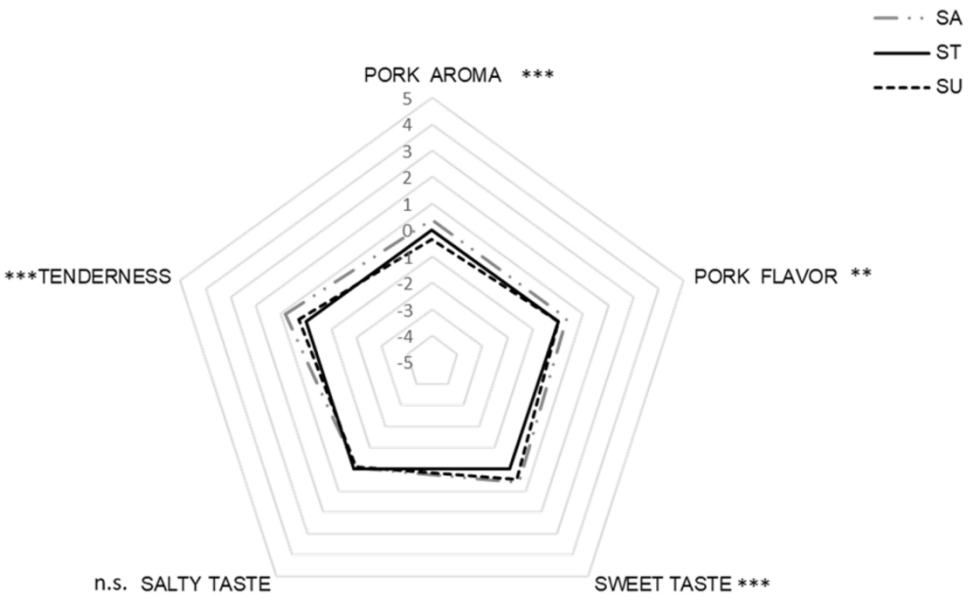

Fig. 1. Mean values of sensory attributes for samples derived from pigs fed the sugary (SU) and salty (SA) diets compared to the samples derived from pigs fed standard diets (ST). n.s. not significant; ** P < 0.01; *** P < 0.001.

159x121mm (300 x 300 DPI)

Sustainable Pig Diets: Partial Grain Replacement with Former Food Products and its impact on Meat Quality

Supplementary Table 1

Analyzed composition (g/100g or MJ/kg on DM) of the two pure former food products used to formulate the experimental diets for growing-finishing pigs, similar to the two pure FFPs used for the diets in post-weaned piglets by Luciano et al. 2020.

Item	Pure SU FFPs[1]	Pure SA FFPs[2]
DM	91.00	87.70
DE (MJ/kg)	19.60	19.40
CP	10.00	11.00
Ash	2.10	2.10
Crude Fats (after hydrolysis)	9.59	7.50
CF	1.60	2.20
Starch	42.50	50.50
NFE	67.80	64.90
TS (expressed in sucrose)	21.00	10.50
Fe (mg/kg)	41.70	95.00
Sodium chloride	0.20	0.15
Amino acids		
Arg	0.48	0.20
His	0.19	0.17
Ile	0.33	0.27
Leu	0.59	0.68
Lys	0.26	0.18
Met	0.05	0.13
Phe	0.40	0.50
Thr	0.25	0.31
Val	0.40	0.27
Ala	0.29	0.66
Asp	0.48	0.40
Cys	0.10	0.10
Glu	2.44	2.87
Gly	0.32	0.48
Pro	0.80	1.34
Ser	0.40	0.54
Tyr	0.22	0.19
Total	8.00	9.29

Abbreviations: DE= digestible energy; CF= crude fiber; NFE= nitrogen-free extracts; TS= total sugars.

[1] Pure SU FFPs: Pure confectionary former food products.

[2] Pure SA FFPs: Pure bakery former food products.