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Effects of bread in the diet of fattening pigs reared extensively

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We evaluated the effects of adding unsold bread (i.e. a low-cost product) to the diet of fattening crossbreed pigs reared outdoors. A total of 27 Goland sows were allocated to three homogeneous groups and fed with different diets: A feed + 15% bread; B feed + 30% bread; C the control group (only feed). The pigs were weighed individually on arrival at the farm, at the start of the experiment, and at slaughter. Growth performance and carcass traits were evaluated. Two sections from the loin were taken from each animal and the following were analyzed: dry matter, crude protein, lipids, ash, fatty acids, pH, color, water-holding capacity, and lipid oxidation. Group B had higher gains and slaughter weights than group C, while group A showed intermediate values. The results show that a diet containing 30% bread facilitates weight gain of pigs, without affecting meat quality and nutritional value.

KEY WORDS: bread / extensive farming / growth performance / meat quality / swine / sustainability.

Around 17% of the total global food production is wasted: 11% in households, 5% in the food service, and 2% in retail [FAO, 2021]. In a circular economy, food waste could be useful as an alternative protein/energy resource to replace some conventional ingredients in animal diets [Luciano *et al.* 2020]. Bread is an excellent source of

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carbohydrates, combining simple and complex sugars in the same food matrix, which is also protein enriched and low in fats [CREA, 2021]. Bread can be dried and ground to provide ingredients for various animal feeds, e.g. for sheep [Eniolorunda 2011, Obeidat *et al*. 2012], chickens [Adegbenro *et al*. 2020; Ayanrinde *et al*. 2014], fish [Lawal *et al.* 2014], and pigs [Kumar *et al*. 2014, Sirtori *et al*. 2007]. In most cases no significant differences were found in growth performances of animals and in the quality of products (meat, eggs, milk) - Ayanrinde *et al*. [2014], Kumar *et al*. [2014], Lawal *et al*. [2014], Obeidat *et al*. [2012]. In some cases, greater daily weight gains and better carcass performances were observed than those obtained with the traditional diet [Adegbenro *et al*. 2020, Eniolorunda 2011, Sirtori *et al*. 2007]. Furthermore, some studies have evaluated the economic impact of this alternative ingredient and found that production costs of animal feed could be reduced [Eniolorunda 2011, Obeidat *et al*. 2012]. In rearing pigs, feed constitutes the greatest cost (about 70%) and affects the pig's performance as well as sustainability of the sector. Pigs compete directly with humans for grains, and the pig industry is threatened by a more than 60% deficiency of these important feed sources [Banik *et al.* 2011] together with the increasing costs of grain [Kumar *et al*. 2014]. Using unsold bread from bakeries at low cost could thus be a feasible solution. There are few studies regarding the use of bread in the diet of pigs and to the best of our knowledge none relate to crossbred pigs reared outdoors. Autochthonous breeds are generally considered more suitable for extensive rearing than crossbreeds. In fact, crossbreeds are optimal for meat production, but their genetic potential is fully expressed especially in intensive farming, where they are confined and more controlled. However, consumers today are more demanding, they require not only high meat quality, but also animal welfare and outdoor farming is considered a more sustainable choice. Tuscany, a region in central Italy, has an ancient tradition of extensive rearing of the local breed Cinta Senese [Franci and Pugliese 2007], but very few livestock producers rear crossbreeds outdoors. The use of bread in the diet for crossbreed pigs could promote the development of this niche sector. Consequently, the aim of this study was to evaluate growth performance and the chemical and physical characteristics of meat after the addition of bread to the conventional diet of crossbred pigs during the fattening phase in extensive conditions.

Material and methods

Animals were handled as outlined by the guidelines of the European Union directive 2010/63/ EU for animal experiments. The approval by the Ethics Committee was not required according to the Italian Legislative Decree March 4, 2014, no. 26 "Implementation of Directive 2010/63/EU on the protection of animals used for scientific purposes". Twenty-seven Goland [(Large White x Landrance) x (Large White x Pietrain)] (6-month-old; average body weight, BW: 130.18±1.49 kg) sows from a local commercial breeding farm were used as experimental animals. The pigs were given auricular tags and allotted to three homogenous groups (A, B, C) in terms of age and weight. The study was conducted on an extensive pig farm near Florence (central Italy), where the animals were kept in three adjacent outdoor pens (9 pigs per pen; 500 m^2/pen) in an area with no additional nutritional value for the pigs. Each pen was equipped with two feeders (4m long) and four pressure drinkers.

The experimental diets were fed to the pigs for 56 consecutive days after an initial 28-day period of adaptation, during which all the pigs were fed with a commercial diet. The three groups of pigs were randomly assigned to one of three dietary treatments: control feed (C); feed plus 15% bread (A); feed plus 30% bread (B). The amount of bread was expressed as a percentage of the feed. The feed was pelleted and produced specifically for fattening pigs. It was composed of maize (55%), barley (25%), *Vicia faba* L. (12%), soybean meal (8%) supplemented with 0.75% lysine, 0.25% methionine, 0.07% Ca, 0.40% P and 0.03% Na. The amount of feed administered was equivalent to 3% of the pig's body weight. Unsold bread was collected every day from the same local bakery. The bread had a homogeneous composition, which was constant throughout the experimental period, and cost 0.05 euros per kg. The diets were administered once a day in the morning and there were no residues. The pigs had access to water for *ad libitum* consumption. The metabolizable energy of feed and bread (Tab. 1) was calculated using the formula of McDonald *et al.* [2011]. The following were measured and are shown in Table 1: dry matter (934.01), crude protein by the Kjeldahl method (945.18), percentage lipids by the Soxhlet method (920.39), crude fiber by the Weende method (978.10), and ash (942.05) [AOAC, 2021].

Table 1. Composition of feed and bread

Items	Feed	Bread
Dry matter, DM (%)%	93.7	76.7
Crude protein (% DM)	14.4	12.9
Ether extract (% DM)	2.5	1.6
Ash (% DM)	2.4	2.2
Crude fiber (% DM)	4.1	2.9
Metabolizable Energy (MJ/kg)	14.23	11.72

The pigs were individually weighed upon arrival on the farm, after a 28-day period of adaptation (initial BW), and after 56 days of the experimental diets (final BW). Before slaughter, pigs were given a 24h rest period with full access to water but not feed, after which they were electrically stunned and slaughtered at an EU-licensed abattoir. Hot carcass weights were recorded and used to calculate hot carcass yield. Carcass length (from the midpoint of the cranial margin of the first rib to the ischium pubic symphysis), ham length (from the medial malleolus to the cranial margin of the ischium pubic symphysis) and the maximum ham width measurements were taken on the right side of each carcass.

After a 24h post-mortem period, from each right half-carcass a steak was cut between the 6th and 8th thoracic vertebra. The *longissimus dorsi* muscle was isolated and used for meat quality determination. Dry matter (934.01), ash (920.153) and crude protein (Kjeldahl method 928.08) were analyzed [AOAC, 2021]. Percentage intramuscular fat content was determined in 5 g of meat with a gravimetric method after extraction following the method presented by Folch et al. (1957) using a chloroform/methanol solution. The lipids were resuspended in 2 mL of chloroform and stored at -20° C until the preparation of fatty acid methyl esters using a methanolic sodium methoxide solution (0.5 N) according to Christie [1982]. For each sample, 1.5 mL of fatty acid methyl esters was injected by the split injection mode into a Perkin Elmer Auto System (Norwalk, CT). The instrument was equipped with an automatic injector, a flame ionization detector (FID), and a capillary column (60 m x 0.25 mm; film thickness 0.25mm; Thermo Scientific TR-FAME). Helium was used as the carrier gas with a flow rate of 1 mL min^{-1}. The initial oven temperature was set at 50°C, after 2 min the temperature was increased at a rate of 1°C min^{-1} to 180°C, and held for 2 min. It was then increased to 200°C and held for 15 min. Finally, the temperature reached 220°C. Injector and detector temperatures were 270°C and 300°C, respectively.

The C9:0 fatty acid was used as an internal standard for recovery determination. The peak areas of individual fatty acids were identified by comparison with the fatty acid standard (Food Industry FAME Mix – Restek Corporation, Bellefonte, PA) and quantified as a percentage of the total fatty acids.

Meat pH was determined with a puncture electrode (Double Pore Slim, Hamilton, Switzerland) equipped on a pH meter with an automatic temperature compensator (pH 2700, Eutech Instruments, the Netherlands). The pH meter was calibrated before each session with buffer solutions at pH 4.01 and 7.01 (HI7004L and HI7007L Hanna instruments, Italy). Meat color was evaluated on a 2.5-cm-thick slice of meat, using a Minolta CR300 colorimeter (Illuminant D 65) (Minolta Camera Co. Ltd, Osaka, Japan), calibrated against a standard white tile in the CIEL*a*b* system, which measures values of lightness (L*), redness (a*), yellowness (b*) coordinates. The a* and b* parameters were used to calculate chroma (C*) and hue (H*) (CIE, 1978). Prior to the color evaluation, each sample was allowed to oxygenate at 4°C for 45 min covered with an oxygen permeable polyethylene film. After removing the polyethylene film, the meat color was determined from three readings per sample. Water holding capacity was determined as drip loss, as described by Lundström and Malmfors (1985). Drip loss was calculated as the weight loss of a meat sample of known weight kept in standardized conditions at 4°C for 24 h and seven days in a plastic container with a double bottom.

Lipid oxidation of samples kept at 4°C for 24 h and seven days was measured by TBARS (thiobarbituric acid reactive substances) using the colorimetric method described by Dal Bosco *et al*. [2009], and the results were expressed as mg malondialdehyde MDA equivalent per kilogram of sample.

Data are presented as means with SE and were analyzed using one-way analysis of variance (ANOVA); means showing significant differences were compared with the use of Tukey's post-hoc test. Statistical significance was considered at $P<0.05$. TBARS data were analyzed using two-way ANOVA with the diet and storage time as the main factors, and the interaction of the main factors was also tested.

Results and discussion

Growth performances are presented in Table 2. The pigs in group B showed a significantly greater BW gain (P=0.001) and average daily gain, ADG (P=0.001) than the two other groups. Group B also showed a greater final BW (P=0.043) and carcass weight (P=0.048) than pigs in group C, while intermediate values were recorded for the animals in group A.

Table 2. Effects of diet on growth performances and carcass measurements

Parameters	Diet						P
	A		B		C		
	mean	SE	mean	SE	mean	SE	
Initial BW (kg)	143.89	3.557	139.89	5.621	142.89	1.975	0.766
Final BW (kg)	169.11^{ab}	5.141	182.44^{a}	4.337	164.00^{b}	5.535	0.043
Carcass weight (kg)	136.89^{ab}	4.479	148.11^{a}	3.835	132.11^{b}	4.951	0.048
Carcass yield (%)	80.70	0.193	81.15	0.179	80.47	0.298	0.297
BW gain (kg)	25.22^{b}	2.881	42.56^{a}	3.258	21.11^{b}	4.906	0.001
ADG (kg)	0.45^{b}	0.051	0.76^{a}	0.058	0.38^{b}	0.087	0.001
Carcass length (cm)	90.56	0.915	91.44	0.604	88.44	1.788	0.219
Ham length (cm)	44.94	0.648	46.11	0.539	45.28	0.450	0.322
Ham width (cm)	27.11	0.660	27.33	0.408	25.94	0.586	0.193

A – feed plus 15% bread; B – feed plus 30% bread; C – control feed; SE –standard error.
^{ab}Within rows means bearing different superscripts differ significantly at P<0.05.

A greater weight gain has also been observed in studies, in which bread was administered as a substitute for some dietary ingredients for pigs [Kumar *et al*. 2014, Sirtori *et al*. 2007]. This appears to be in line with recent works [Ottoboni *et al*. 2019, Tretola *et al*. 2019] that defined bakery products as a fortified version of cereals. Bread is a food source with a high metabolizable energy compared to other sources of carbohydrates such as corn, thanks to its sugar content (more than 200 g/kg) and highly digestible starch (44.5%) [Kwak and Kang 2006]. However, if bread was provided as the only food, minor increases occurred [Takahashi *et al*. 2012]. This is probably due to the fact that the proteins contained in cereals, from which the bread is derived, are generally characterized by a very high content of proline and glutamine, but a low content of lysine and other essential amino acids [Doll 1984]. In our study, adding bread to the diet caused no problems. On the other hand, other studies showed that replacing 75% of the diet with bread led to constipation, as bread is low in fiber. This may explain the minor weight gain observed in pigs kept in the indoor management system [Kumar *et al*. 2014]. In our study the pigs consumed less bread and were able to move freely in their pens, thus favoring intestinal peristalsis and preventing constipation.

Carcass measurements are presented in Table 2. Although the pigs that received a higher percentage of bread tended to be larger, the differences were not statistically significant. This coincides with findings that showed that the morphometric characteristics of crossbred pigs are influenced more by the genetic type than by feeding [Gispert *et al*. 2007, Krasnova *et al.* 2020].

No significant differences emerged between the groups for any meat quality parameters considered (Tab. 3). However, there was a trend towards a higher percentage of intramuscular lipids in the meat of animals in group B. This trend appears to be in line with another study that found a significant increase in the percentage of intramuscular fat of pigs fed with a higher amount of bread [Takahashi *et al*. 2012]. This seems to be due to the reduced lysine content and the low lysine/protein ratio in these diets which, as verified by several authors, in the fattening phase promotes an increase in fat deposits [Iwamoto *et al*. 2005, Witte *et al*. 2000].

Table 3. Effects of diet on the chemical composition of meat (percentage on wet basis)

Parameters	Diet						P
	A		B		C		
	mean	SE	mean	SE	mean	SE	
Dry matter (%)	27.03	0.900	26.72	0.444	27.40	0.713	0.274
Crude protein (%)	23.93	0.219	23.79	0.404	23.39	0.574	0.650
Lipid (%)	2.73	0.269	3.13	0.370	2.57	0.157	0.360
Ash (%)	1.03	0.035	0.98	0.058	1.04	0.021	0.582

A – feed plus 15% bread; B – feed plus 30% bread; C – control feed; SE –standard error.
[ab]Within rows means bearing different superscripts differ significantly at P<0.05.

Table 4. Effects of diet on the fatty acid profile of intramuscular fat of meat (percentage of fatty acid methyl esters)

Fatty acids	Diet						P
	A		B		C		
	mean	SE	mean	SE	mean	SE	
C10:0 (%)	0.18	0.006	0.17	0.005	0.16	0.007	0.475
C12:0 (%)	0.20	0.026	0.20	0.000	0.15	0.024	0.339
C14:0 (%)	1.48	0.045	1.53	0.055	1.24	0.139	0.072
C16:0 (%)	26.07	0.390	26.59	0.541	25.83	0.376	0.477
C16:1 n-7 (%)	3.80	0.154	3.75	0.135	3.60	0.156	0.614
C17:0 (%)	0.17	0.000	0.22	0.000	0.18	00.017	0.577
C17:1 (%)	0.28	0.015	0.31	0.088	0.25	0.023	0.590
C18:0 (%)	12.85	0.379	13.29	0.835	13.39	0.470	0.577
C18:1 n-9 (%)	41.62	0.469	40.99	0.779	41.43	0.909	0.830
C18:1 n-7 (%)	4.36	0.115	4.08	0.097	4.10	0.133	0.182
C18:2 n-6 (%)	7.70	0.274	7.77	0.553	7.69	0.428	0.988
C18:3 n-3 (%)	0.35	0.129	0.19	0.003	0.21	0.011	0.403
C20:0 (%)	0.18	0.005	0.18	0.000	0.16	0.003	0.135
C20:1 (%)	0.82^{ab}	0.027	0.72^{b}	0.027	0.84^{a}	0.047	0.045
C20:3 n-6 (%)	0.20	0.006	0.21	0.008	0.17	0.012	0.059
C20:4 n-6 (%)	1.56	0.146	1.36	0.127	1.23	0.008	0.196
C22:5 n-3 (%)	0.19	0.005	0.23	0.000	0.15	0.014	0.078
SFA (%)	40.61	0.674	41.51	0.703	40.85	0.793	0.665
MUFA (%)	50.79	0.515	49.25	0.571	50.04	1.190	0.426
PUFA (%)	9.53	0.889	9.21	0.743	9.11	0.569	0.877

A – feed plus 15% bread; B – feed plus 30% bread; C – control feed; SE –standard error.
SFA, MUFA, PUFA, sum of all saturated, monounsaturated and polyunsaturated fatty acids, respectively.
[ab]Within rows means bearing different superscripts differ significantly at P<0.05.

Table 4 shows fatty acids of the intramuscular fat of meat. There appear to be no studies in the literature to report the fatty acid composition of intramuscular fat in pigs fed with bread, despite the fact that this type of analysis is important for assessing meat quality, particularly in terms of nutritional and technological value. The values of the individual fatty acids fall within the standards of the fatty acid profile of pork [Alonso *et al*. 2009, Kasprzyk *et al*. 2015]. No significant differences were found between the three different diets except for eicosenoic acid (C20:1) (P=0.045). This indicates that the addition of bread to the diet does not make a substantial difference to the fatty acid composition of intramuscular fat of meat.

Concerning the physical characteristics of meat, again no statistically significant differences were found in any of the parameters considered (Tab. 5). In fact, no differences in pH values have been found in other studies on the use of bread in the diet of crossbred pigs [Kwak and Kang 2006, Prandini *et al*. 2017] and Cinta Senese [Sirtori *et al*. 2007].

Table 5. Effects of diet on physical characteristics of meat

Parameters	Diet						P
	A		B		C		
	mean	SE	mean	SE	mean	SE	
pH	5.40	0.084	5.68	0.069	5.54	0.068	0.240
*L**	51.13	1.430	50.48	1.150	49.93	1.020	0.783
*a**	10.52	0.391	9.95	0.583	10.98	0.466	0.341
*b**	4.59	0.588	3.96	0.407	4.30	0.307	0.621
*C**	11.55	0.541	10.75	0.642	11.83	0.474	0.379
*h**	23.05	2.15	21.59	1.60	21.44	1.46	0.778
Drip loss1 (%)	0.68	0.093	0.57	0.059	0.48	0.031	0.102
Drip loss7 (%)	2.10	0.211	1.95	0.225	1.51	0.093	0.086

A – feed plus 15% bread; B – feed plus 30% bread; C – control feed; SE –standard error.

The measurement of color index L* of pig meat used in the study is in line with the ideal value L* of 49, corresponding to a reddish pink [NPB, 2021]. The amount of bread used for this experiment did not lead to differences in meat color as in other works where bread was fed to crossbreed pigs [Takahashi *et al*. 2012] and to Cinta Senese [Sirtori *et al*. 2007]. One study that replaced 50% of the diet with food waste, including bread, observed a paler coloration of the meat [Kwak and Kang 2006]. In contrast, in pigs fed only with food waste containing 12% bread [Kjos *et al.* 2000], the L* index was lower and consequently the meat was darker. Large quantities of bread in the diet would thus seem to influence meat color.

The water holding capacity showed no differences between the different diets. In line with our results, other authors also found no differences in drip loss of animals fed with different percentages of bread in the diet [Kjos *et al*. 2000, Kwak and Kang 2006, Sirtori *et al*. 2007].

In terms of lipid oxidation of meat (Tab. 6), no significant differences were found between the diets. The limit value indicating rancidity is fixed at 1-2 mg of MDA per kg of meat [Lanari *et al.* 1995]. Despite the natural oxidation of lipids during the seven days of storage, we can deduce that this did not produce any substances that might make meat unacceptable to consumers, and likewise for all the diets. The addition of bread did not therefore cause an increase in lipid oxidation in the meat samples analyzed.

Our results show that unsold bread can be added to the diet of fattening crossbred pigs reared extensively without affecting the physical-chemical meat quality. It should be underlined that for the first time the fatty acid composition was analyzed in pigs fed with bread, demonstrating that the nutritional value was unaffected. To obtain a significant increase in growth performance, 30% of the diet should consist of bread, since smaller quantities did not produce significant results.

In conclusion, transforming bread leftovers has economic benefits and has a positive impact on the environmental sustainability of pig farms, since the use of unsold bread contributes to reducing food waste.

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Table 6. Effects of diet and storage time on lipid oxidation of meat

Parameters	Diet (D)						Days of storage (T)				P	
	A		B		C		0		7		D	T
	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE		
TBARS (mg MDA per Kg)	0.178	0.008	0.179	0.008	0.179	0.008	0.000^a	0.000	0.358^b	0.005	0.923	<0.001

A – feed plus 15% bread; B – feed plus 30% bread; C – control feed; SE –standard error.
^{ab}Within rows means bearing different superscripts differ significantly at P<0.05.

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