# Decreasing the level of hemicelluloses in sow's lactation diet affects the milk composition and post-weaning performance of low birthweight piglets.

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## Abstract

Hemicelluloses (HC) are polysaccharides constituents of the cell walls of plants. They are fermented in the gut to produce volatile fatty acids (VFA). The present study investigated the effects of decreasing HC level in sow's lactation diet on sow performances, offspring development and milk composition. From 110 days (d) of gestation until weaning (26±0.4 d post-farrowing), 40 Swiss Large White sows were assigned to one of the four dietary treatments: (1) T12 (HC: 120.6g/kg), (2) T11 (HC: 107.6 g/kg), (3) T9 (HC: 86.4g/kg) and (4) T7 (HC: 71.9g/kg). Milk was collected at 3 and 17d of lactation. At birth, piglets were divided into two groups according to their birthweight (BtW): normal (N-BtW; BtW > 1.20 kg) or low (L-BtW; BtW ≤ 1.20 kg). Decreased HC levels in the maternal diet linearly increased ($P \le 0.05$) the body weight of L-BtW piglets at two weeks post-weaning and linearly decreased ($P \le 0.05$) diarrhoea incidence and duration in this category. The concentrations of copper, threonine and VFA, as well as the proportion of butyrate, in milk linearly increased (*P*

≤ 0.05), whereas lactose content linearly decreased ($P \leq 0.05$) with decreased HC in the maternal diet. The present study provides evidence that decreasing HC level in sow's lactation diet can positively affect the composition and VFA profile of milk and ultimately favour the growth and health of L-BtW piglets.

**Keywords:** Dietary fibres, lactose, pigs, volatile fatty acids, butyrate

## Introduction

Hemicelluloses (HC) represent a complex group of polysaccharides present in the cell walls of all plants, consisting mainly of pentoses (D-xylose and D-arabinose), hexoses (D-galactose, D-glucose and D-mannose) and uronic acids (Huang et al., 2021). As part of dietary fibres (DF), they can resist digestion by endogenous enzymes of the gut. Thus, they can reach the large intestine and promote the growth and activity of beneficial bacteria that produce volatile fatty acids (VFA) (Lattimer and Haub, 2010). VFA, namely, acetate, propionate and butyrate, provide up to 28% of the energy requirements in growing pigs and even more in sows, where they can be absorbed and transferred to the milk and serve as an energy source for milk synthesis (Noblet and Le Goff, 2001; Tian et al., 2020). A previous study focused on increasing the level of DF in sow's gestation diet and showed that adding up to 20% DF increases colostrum fat content, as well as colostrum intake, of low birthweight (L-BtW) piglets and decreases litter mortality during the suckling period (Loisel et al., 2013). To our knowledge, the effects of HC level on lactating sows have never been investigated. However, this aspect can be relevant, since sow nutrition during lactation may also positively affect the development and gut health of piglets (Paßlack et al., 2015).

Therefore, the present study aims to fill this gap by comparing four diets characterised by similar total DF and crude fibre contents and by different HC levels by varying the sources of DF. We hypothesised that decreasing the level of HC in sow's lactation diet may affect gut fermentation and ultimately modify milk composition.

## Materials and methods

### ***Animals, housing and treatments***

The experiment was conducted during late gestation and lactation of 40 Swiss Large White sows from five farrowing batches. Approximately 10 days before the expected time of farrowing, sows were moved to farrowing rooms arranged with individual 7.1 $m^2$ farrowing crates, consisting of a 5.89 $m^2$ concrete solid floor and a 1.21 $m^2$ concrete slatted floor. Each crate was equipped with an electronic sow feeder (Schauer Spotmix, Schauer Agrotronic GmbH, Austria), nipple drinker and a heated covered area for piglets. The ambient temperature was maintained at 24 °C, and artificial lights were on from 0800 h to 1700 h. On day 110 of gestation, the sows were randomly allocated to one of the four experimental diets based on parity (mean ± SEM: 3.5 ± 0.7) and BW (mean ± SEM: 286.5 ± 13.6). Parturition was induced when gestation period exceeded 116 days with an intramuscular injection of 1 ml (0.25 g/ml) of cloprostenol (Estrumate®, MSD Animal Health GmbH, Luzern, Switzerland). Within the first 24 h following birth, piglets were identified by an individual ear tag and received iron injection (Feridex® 10%, AMAG Pharmaceuticals, Inc., Waltham, USA). Piglets weighing less than 800 g at birth were excluded from the experiment. To adjust litter size to an average of 12 piglets per sow, cross-fostering was carried out only on male piglets 24 h post-farrowing. After anaesthetisation, the male piglets were castrated in the second week. Piglets were weaned on day 25.7 ± 0.44 (mean ± SEM) of age but were kept in their respective farrowing crates until 2 weeks post-weaning. The heating nest temperature was set at 40 °C following birth and then gradually decreased by 0.5 °C per day to reach a final temperature of 32 °C

***Diets and feeding***

The experimental diets were formulated to be isonitrogenous and isocaloric (Table 1) and to differ in DF sources and HC content: (1) T12 (HC: 121 g/kg), (2) T11 (HC: 108 g/kg), (3) T9 (HC: 86 g/kg) and (4) T7 (HC: 72 g/kg). The daily feed allowance was calculated according to the current Swiss feeding recommendations for pigs (Agroscope, 2018). Sows had *ad libitum* access to water and were provided with moderate quantities of straw bedding. During lactation, the feed allowance was gradually increased by 0.5 kg/day until *ad libitum* feeding on day 12 of lactation approximatively. All diets were delivered three times per day in three equal meals using a computerised feed delivery system (Schauer Spotmix, Schauer Agrotronic GmbH, Austria). Throughout the experiment, the feed refusals of the sows were weighed daily to calculate actual feed intake. From day 18.7 ± 0.44 of age (mean ± SEM) to 2 weeks post-weaning (mean ± SEM: day 39.7 ± 0.44 of age), piglets had *ad libitum* access to a post-weaning standard starter diet and water. The post-weaning starter diet contained 170 g/kg crude protein, 58 g/kg fat, 50 g/kg crude fibre and 14 MJ/kg digestible energy.

**Table 1. Ingredients and composition of the sow's lactation diet**

| | Dietary Treatments[1] | | | |
|---|---|---|---|---|
| Item | T12 | T11 | T9 | T7 |
| Ingredients (%) | | | | |
| Barley, ground | 54.4 | 38.7 | | 4.7 |
| Oat flakes | | | 4.0 | 18.2 |
| Corn, ground | 10.3 | | 26.9 | 16.0 |

| | | | | |
|---|---|---|---|---|
| Rye | | 25.0 | 10.0 | |
| Wheat, ground | | | 13.1 | 15.0 |
| Wheat starch | 4.0 | 4.0 | 4.0 | 4.0 |
| Molasses | | | | 4.0 |
| Animal fat RS 65 | 2.4 | 2.4 | 3.0 | 3.8 |
| Potato protein | 10.0 | 10.0 | 10.0 | 10.0 |
| Soybean meal | 10.0 | 10.0 | 10.0 | 10.0 |
| Flaxseed Meal | 0.6 | | | |
| Rapeseed meal | | 0.4 | | 1.7 |
| Oat hulls | | | 4.0 | 8.0 |
| Lupin | | | 2.5 | |
| Wheat bran | | | 4.0 | |
| Beet pulp | 3.0 | 5.0 | 4.0 | |
| L-lysine-HCL | 0.070 | 0.057 | 0.057 | 0.056 |
| DL-methionine | 0.200 | | | |
| L-threonine | 0.050 | | | 0.050 |
| L-tryptophan | 0.020 | 0.006 | 0.013 | 0.003 |
| Dicalcium phosphate | 0.94 | 0.70 | 0.82 | 0.85 |
| Calcium carbonate | 1.57 | 1.38 | 1.39 | 1.47 |
| Salt | 0.59 | 0.52 | 0.42 | 0.41 |
| Pellan[2] | 0.40 | 0.40 | 0.40 | 0.40 |
| Celite | 1.00 | 1.00 | 1.00 | 1.00 |
| Premix[3] | 0.40 | 0.40 | 0.40 | 0.40 |
| Natuphos 5000 G[4] | 0.01 | 0.01 | 0.01 | 0.01 |
| Gross chemical composition analysed (g/kg as fed) | | | | |
| Dry matter | 900 | 894 | 897 | 900 |
| Crude protein | 193 | 191 | 192 | 196 |
| Fat | 51 | 46 | 57 | 60 |
| Crude fibre | 43 | 43 | 47 | 46 |
| Ash | 63 | 61 | 60 | 63 |
| NDF | 184 | 174 | 163 | 154 |
| ADF | 63 | 67 | 76 | 82 |
| Hemicelluloses[5] | 121 | 108 | 86 | 72 |
| Total dietary fibres | 210 | 227 | 220 | 203 |
| Low-molecular-weight dietary fibres | 18 | 23 | 18 | 14 |
| Soluble dietary fibres | 43 | 44 | 35 | 28 |
| Insoluble dietary fibres | 149 | 160 | 167 | 161 |
| IDF/SDF[6] | 3.46 | 3.63 | 4.77 | 5.75 |
| Calcium | 9.4 | 9.4 | 9.3 | 8.7 |
| Phosphorus | 5.0 | 4.6 | 5.0 | 4.7 |

| | | | | |
|---|---|---|---|---|
| Gross chemical composition calculated | | | | |
| Digestible energy (MJ/kg) | 14.1 | 14.1 | 14.1 | 14.1 |
| Digestible phosphorus (g/kg as fed) | 3.1 | 2.8 | 2.8 | 2.8 |
| Digestible essential amino acids (g/kg as fed) | | | | |
| Lysine | 9.6 | 9.6 | 9.6 | 9.6 |
| Methionine | 4.9 | 2.9 | 3.0 | 3.0 |
| Threonine | 6.9 | 6.3 | 6.4 | 6.9 |
| Tryptophan | 2.0 | 1.8 | 1.8 | 1.8 |

[1]T12 = Sow's lactation diet containing 12% of hemicelluloses; T11 = Sow's lactation diet containing 11% of hemicelluloses; T9 = Sow's lactation diet containing 9% of hemicelluloses; T7 = Sow's lactation diet containing 7% of hemicelluloses.

[2]Pellet binding aid: Pellan, Mikro-Technik, Bürgstadt, Germany.

[3]Supplied per kg of diet: vitamin A, 8000 IU; vitamin D3, 800 IU; vitamin E, 40 mg; menadione, 2 mg; thiamine, 2 mg; riboflavin, 5 mg; biotin, 0.1 mg; niacin, 20 mg; pantothenic acid, 20 mg; iodine (as calcium iodate), 0.55 mg; copper (as copper sulphate), 7 mg; manganese (as manganese oxide), 20 mg; zinc (as zinc oxide), 55 mg; selenium (as sodium selenite), 0.2 mg.

[4]Phytase supplemented with 500 units of *Aspergillus niger* phytase/kg diet.

[5]Hemicellulose: calculated as the difference between NDF and ADF.

[6]Ratio of insoluble to soluble dietary fibres

### *Sow and piglet performance*

The BW of the sows, body condition score (BCS) and backfat thickness were recorded at the 110th day of gestation and during farrowing and weaning. Weight loss during lactation was calculated as the weight difference during farrowing and weaning. BCS was determined according to a scale ranging from 1 (*very thin*) to 6 (*obese*) points (Dourmad et al., 2001), including intermediate values of 0.33 points. Backfat thickness was measured on each side at 65 mm of the dorsal midline at the level of the last rib (P2) using a digital ultrasound back-fat indicator (Renco Lean Meter Digital Backfat Indicator, Renco Corporation, Minneapolis, Minnesota, USA). Backfat thickness loss during lactation was then calculated as the difference between backfat thickness measurements during farrowing and weaning. At farrowing, the number of born alive, stillborn and mummified piglets were recorded within each litter. Farrowing was recorded using a digital video recorder to estimate the farrowing duration, which is defined as the time span between the time of birth of the first and last piglet of the litter. Furthermore, the time between the start of the farrowing and the first piglet suckling was also recorded. At birth, the piglets were individually weighed, and crown-to-rump length and body circumference were recorded. Piglets were then individually weighed 5 and 16 days postpartum, during weaning (mean ± SEM: 25.7 ± 0.44 days of age) and at 1 (mean ± SEM: 32.7 ± 0.44 days of age) and 2 weeks post-weaning (mean ± SEM: 39.7 ± 0.44 days of age). The average daily gain (ADG) and litter weight during birth and weaning were calculated from these data. Milk yield was calculated as the individual piglet gain summed in the same litter multiplied by a numerical coefficient of 4.2 (Van der Peet-Schwering et al., 1998). The indices of body conformation were calculated based on the measurements of the individual birthweight (BtW) and the crown-to-rump length. The body mass index was calculated as the ratio of BtW to the squared value of the crown-to-rump length, and the ponderal index was calculated as the ratio of BtW to the cubic value of the crown-to-rump length (Hales et al., 2013). In addition, piglets were divided into two BtW groups: normal (N-BtW; BtW > 1.20 kg) or low (L-BtW; BtW ≤ 1.20 kg). From 1 week before weaning and onwards, feed intake per pen and the occurrence of diarrhoea were recorded daily. Diarrhoea percentage was determined according to a daily faecal score assessed using a scale from 0 = *no diarrhoea* to 1 = *diarrhoea*.

***Sample Collection***

Within each farrowing series, feed samples of the four diets were collected weekly and pooled over the experimental period to determine the chemical composition. On days 3 and 17 of lactation, milk samples were manually collected from all functional teats after an injection of 2 ml of oxytocin (Intertocine-S, MSD Animal Health GmbH, Luzern, Switzerland). Before milking, the piglets were temporarily isolated from the sow for 2 h, and the teats were cleaned with humid wipes. One aliquot of milk was refrigerated at 5 °C with 4 mg of bronopol to determine somatic cell concentration, and three aliquots were immediately stored at −20 °C for further analysis.

## ***Analytical Methods***

### *Feed Analysis*

After being ground to pass a 1-mm screen (Brabender rotary mill; Brabender GmbH & Co. KG, Duisburg, Germany), feed samples were analysed for dry matter  content by heating at 105˚C for 3h followed by incineration at 550°C until a stable mass was reached to determine the ash content according to ISO 5984:2002 (prepASH, Precisa Gravimetrics AG, Dietikon, Switzerland). An inductively coupled plasma optical emission spectrometer (ICP-OES, Optima 7300 DV; Perkin-Elmer, Schwerzenbach, Switzerland) was used to measure mineral content (European Standard EN 15510:2008). The CP content was calculated as nitrogen (N) content multiplied by a coefficient of 6.25, where N was determined with the Dumas method (ISO 16634–1:2008). Fat content was extracted with petrol ether after acid hydrolysis (ISO 6492:1999). Different categories of fibres were analysed by standard protocols. Crude fibre content was determined gravimetrically (ISO 6865:2000) by incineration of residual ash after acid and alkaline digestions using a fibre analyser (Fibretherm Gerhardt FT-12, C. Gerhardt GmbH & Co. KG, Königswinter, Germany). The NDF and ADF contents (ISO 16472:2006 for NDF and ISO 13906:2008 for ADF) were analysed with the same fibre analyser (Fibretherm Gerhard FT-12, C. Gerhardt GmbH & Co. KG, Konigswinter, Germany) and were expressed without residual ash. NDF determination was evaluated with heat stable amylase and sodium sulfite and expressed without residual ash after incineration at 600°C for 3 h. Soluble (SDF), insoluble (IDF) and low-molecular-weight DF contents were measured according to AOAC Method 2011.25, and the total DF content was calculated as the sum of the three aforementioned types of DFs.

*Milk Analysis*

The dry matter of the frozen milk samples was determined after freeze-drying (Christ DELTA 2-24 LSC, Kühner AG, Birsfelden, Switzerland) for 70 hours. Subsequently, freeze-dried samples were milled with a mortar. Residual dry matter, ashes, mineral and CP contents were analysed as previously described for feed chemical analysis, except that a multiplicative coefficient of 6.38 was applied for the calculation of CP. Except for tryptophan, all amino acids were determined as described in ISO 13903:2005. Briefly, after oxidation, 24 h of acid hydrolysis occurred with 6M HCl and derivatization with AccQ-Tag Ultra reagent (Waters corporation, Milford, USA USA), the amino acid profile was determined by ultra-high-performance liquid chromatography (UHPLC) coupled with a UV detector (Vanquish, Thermo Scientific, Reinach, Switzerland. Tryptophan content was quantified by HPLC (LC 1290 Infinity II LC System, Agilent Technologies, USA) according to ISO 13904:2016. Gross energy content was determinate by combustion in a calorimetric vessel under pure oxygen condition using an adiabatic bomb calorimeter (AC600 Semi-Automatic Calorimeter, Leco Corporation, USA) (ISO 9831:1998). Lactose content was determined by enzymatic testing with β-galactosidase and galactose dehydrogenase (Enzytec TM Liquid Lactose/D-Galactose Ref. No. E8110, R-Biopharm AG, Darmstadt, Germany). Somatic cells count (ISO 13366-2) was determined by flow cytometry (Somacount FC, Bentley Instruments Inc., USA). Fatty acid methyl esters, as described by Kragten et al. (2014), and the VFA profile (ISO 15884:2002) (ISO 15885:2002) were determined by gas-liquid chromatography (Gaschromatograph Series II Agilent 6850, Agilent Technologies 2000, USA and Gaschromatograph Serie Agilent 6890, Agilent Technologies 2000, USA, respectively). Fat content was determined as total fatty acids multiplied by a coefficient of 1.05.

### *Statistical Analysis*

Due to health problems that could not be related to the dietary treatment, one T9 sow was excluded from the experiment. Data were analysed by ANOVA using the 'lme' and the 'glmmPQL' function of the *nlme* package of R Studio (version 4.0.2 for Windows). Regarding sow performance, milk composition and VFA profile, the sow was the experimental unit; the pen was the experimental unit regarding piglet feed intake and litter performance; and the piglet was the experimental unit of piglet's individual performance, days and percentage of diarrhoea. Linear regression models, including the treatment and the farrowing batch as fixed effects, were used to fit data related to sow performance, litter performance, piglet feed intake and days with diarrhoea. Data related to piglets' individual performance were analysed using a linear mixed-effects model, including the treatment and the farrowing batch as fixed effects and the sow as random effects. Milk composition and VFA profile were analysed with a linear mixed-effects model and fitted in repeated measurements, including the treatment, the farrowing batch, the sampling day, and the interaction between the treatment and sampling day as fixed effects and the sow as random effect. Before analysis, logarithmic transformation was applied to the milk fatty acid and milk VFA data due to the non-normality of the residuals. The percentage of diarrhoea was analysed using a generalised linear mixed model using Penalized Quasi-Likelihood, including the treatment, the farrowing batch and the day as fixed effects and the piglet as a random factor. Orthogonal polynomial contrasts were implemented to evaluate the linear or quadratic effects of decreasing HC level. The results are expressed as the least square means ± SEM. Linear and quadratic effects were considered significant at $P \leq 0.05$.

## Results

### *Sows' performance*

The sow BW, BCS and backfat thickness on day 110 of gestation and during farrowing and weaning were not influenced by the dietary treatment, resulting in similar weight and backfat thickness losses during the lactation period. Daily feed intake in the pre-farrowing period and during lactation did not differ between treatments. Fibre intake was partially influenced by dietary treatments. In both the pre-farrowing and lactation periods, the NDF, HC, (linear effects; $P < 0.01$), low-molecular-weight DF and SDF intake decreased (linear and quadratic effects; $P < 0.01$), and the ADF intake increased (linear effect; $P < 0.01$) with decreasing HC levels in the diet. A quadratic effect ($P \leq 0.04$) of the HC level was found in the diets on the intake of total DFs in the pre-farrowing and lactation periods. At birth, litter traits, such as total born, born alive and stillborn piglets, did not differ, leading to comparable litter weights in the four treatments. Likewise, the dietary treatments had no effect on the total number of piglets weaned and, consequently, on litter weight at weaning. Farrowing duration and the time between the start of the farrowing and the first piglet suckling were not influenced by dietary treatments. During the entire lactation period, milk yield was not influenced by the dietary treatments, with an average estimated production of 10.38 kg/day per sow (Table 2).

**Table 2. Effect of decreasing hemicelluloses level in lactation diet on sow's performance**

| | [1]Dietary Treatments | | | | | [2]Contrasts | |
|---|---|---|---|---|---|---|---|
| Item | T12 | T11 | T9 | T7 | SEM | *L* | *Q* |
| Sows | | | | | | | |
| Number of sows, *n* | 10 | 10 | 9 | 10 | | | |
| Range of parity, *n* | 3.8 | 3.8 | 3.5 | 3.5 | 0.69 | 0.51 | 0.99 |
| Farrowing duration, min | 308 | 337 | 321 | 262 | 70.7 | 0.54 | 0.44 |
| Body weight, kg | | | | | | | |
| D110 | 284 | 291 | 284 | 287 | 13.6 | 0.71 | 0.89 |
| Farrowing | 264 | 267 | 269 | 272 | 14.1 | 0.67 | 0.99 |
| Weaning | 233 | 238 | 248 | 246 | 12.5 | 0.39 | 0.78 |
| Weight loss in lactation, kg | 30.6 | 28.7 | 20.9 | 26.1 | 2.58 | 0.19 | 0.30 |
| BCS, *n* | | | | | | | |
| D110 | 4.09 | 4.10 | 4.03 | 3.83 | 0.129 | 0.79 | 0.18 |
| Farrowing | 3.58 | 3.59 | 3.40 | 3.64 | 0.148 | 0.96 | 0.40 |
| Weaning | 2.71 | 2.62 | 2.81 | 2.94 | 0.246 | 0.42 | 0.62 |
| Backfat thickness, mm | | | | | | | |
| D110 | 13.8 | 15.8 | 14.8 | 12.7 | 0.88 | 0.31 | 0.23 |
| Farrowing | 13.7 | 14.6 | 12.7 | 15.6 | 0.88 | 0.34 | 0.24 |
| Weaning | 11.3 | 11.9 | 11.5 | 12.9 | 0.71 | 0.18 | 0.52 |
| Backfat thickness loss in lactation, mm | 2.38 | 2.66 | 1.25 | 2.67 | 0.505 | 0.82 | 0.24 |
| Milk yield, kg/day | 10.61 | 10.85 | 10.09 | 9.97 | 0.720 | 0.41 | 0.79 |
| Feed intake, kg/day | | | | | | | |
| Pre-farrowing | 2.93 | 3.03 | 3.03 | 3.00 | 0.155 | 0.75 | 0.68 |
| Lactation | 5.67 | 5.93 | 5.77 | 5.87 | 0.237 | 0.69 | 0.73 |
| Fibre intake, g/day | | | | | | | |
| Pre-farrowing | | | | | | | |
| Crude fibre | 127 | 129 | 141 | 139 | 7.0 | 0.13 | 0.74 |
| NDF | 538 | 527 | 492 | 461 | 26.1 | 0.03 | 0.69 |
| ADF | 185 | 202 | 230 | 248 | 11.3 | <0.01 | 0.97 |
| Hemicelluloses | 353 | 325 | 261 | 213 | 15.1 | <0.01 | 0.48 |
| Total dietary fibres | 614 | 688 | 667 | 610 | 33.1 | 0.82 | 0.04 |
| Low-molecular-weight dietary fibre | 53 | 70 | 55 | 42 | 2.8 | <0.01 | <0.01 |
| Soluble dietary fibres | 133 | 126 | 106 | 83 | 5.8 | <0.01 | <0.01 |
| Insoluble dietary fibres | 436 | 485 | 506 | 484 | 24.8 | 0.14 | 0.14 |
| Lactation | | | | | | | |
| Crude fibre | 246 | 254 | 269 | 272 | 10.4 | 0.06 | 0.81 |
| NDF | 1043 | 1033 | 937 | 903 | 41.3 | <0.01 | 0.75 |
| ADF | 359 | 396 | 439 | 484 | 16.4 | <0.01 | 0.80 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Hemicelluloses | 685 | 638 | 498 | 418 | 25.3 | <0.01 | 0.49 |
| Total dietary fibres | 1190 | 1350 | 1270 | 1190 | 51.1 | 0.76 | 0.02 |
| Low-molecular-weight dietary fibre | 102 | 137 | 104 | 82 | 4.6 | <0.01 | <0.01 |
| Soluble dietary fibres | 244 | 261 | 202 | 163 | 9.6 | <0.01 | <0.01 |
| Insoluble dietary fibres | 845 | 950 | 964 | 947 | 37.1 | 0.06 | 0.09 |
| Suckling piglets | | | | | | | |
| First piglet suckling, min | 35 | 28 | 20 | 38 | 11.0 | 0.98 | 0.23 |
| Number of piglets per litter, *n* | | | | | | | |
| Total born | 13.5 | 13.7 | 13.5 | 14.3 | 1.12 | 0.65 | 0.76 |
| Born alive | 12.8 | 12.4 | 11.4 | 12.7 | 1.27 | 0.82 | 0.49 |
| Stillborn | 0.7 | 1.3 | 2.1 | 1.6 | 0.65 | 0.22 | 0.40 |
| After cross-fostering | 11.4 | 11.4 | 11.5 | 11.6 | 0.79 | 0.85 | 0.91 |
| Weaned | 10.7 | 10.9 | 11.3 | 10.7 | 0.76 | 0.94 | 0.60 |
| Litter weight, kg | | | | | | | |
| At birth | 20.5 | 20.5 | 21.1 | 20.3 | 1.63 | 0.99 | 0.81 |
| At weaning | 81.9 | 83.9 | 78.0 | 79.4 | 5.50 | 0.59 | 0.96 |

[1]T12 = Sow's lactation diet containing 12% of hemicelluloses; T11 = Sow's lactation diet containing 11% of hemicelluloses; T9 = Sow's lactation diet containing 9% of hemicelluloses; T7 = Sow's lactation diet containing 7% of hemicelluloses.

[2]Contrasts: *L* = Linear; *Q* = Quadratic.

### *Piglets' individual performance*

Body characteristics, such as body circumference, crown-to-rump length, body mass index and ponderal index, were not affected by the lactation diet of the sows (Table 3). Similarly, piglet BW development, ADG and feed intake were not affected by the dietary treatments. During the first week post-weaning, the incidence of diarrhoea and the number of days with diarrhoea were similar among the treatments. By contrast, during the second week of post-weaning, a quadratic increase ($P \leq 0.05$) in the incidence of diarrhoea and the number of days with diarrhoea was observed with decreasing HC level. When focusing on the two BtW categories, the effect of the sow diets in the L-BtW group showed interesting observations (Table 4). Excluding the incidence of diarrhoea and the number of days with diarrhoea that linearly increased during the second week post-weaning ($P < 0.01$) with decreased HC level, no dietary effects were observed in N-BtW piglets (Supplementary Table 1). Although BW development was similar from birth to 1 week post-weaning, the decrease in HC level in the sow diets increased (linear effect; $P = 0.02$) the BW of L-BtW piglets at 2 weeks post-weaning. Likewise, the ADG of the L-BtW pigs remained similar among the dietary treatments in the suckling period. Nevertheless, decreasing the HC level in the maternal diet improved ($P \leq 0.05$) the ADG of L-BtW piglets in the second week post-weaning and thereby the overall ADG of the L-BtW piglets during the experiment. In the first week post-weaning, the dietary treatments did not affect either the incidence of diarrhoea or the days with diarrhoea of L-BtW piglets. In the second week post-weaning, the incidence of diarrhoea and days with diarrhoea linearly decreased ($P < 0.01$) with decreased HC level in the maternal diet.

**Table 3. Effect of decreasing hemicelluloses level in the maternal diet on the performance of piglets**

| | [1]Dietary Treatments | | | | SEM | [2]Contrasts | |
|---|---|---|---|---|---|---|---|
| | T12 | T11 | T9 | T7 | | *L* | *Q* |
| Body measurements at birth, cm | | | | | | | |
| Crown-to-rump length | 28.7 | 28.9 | 28.8 | 28.4 | 0.53 | 0.60 | 0.56 |
| Body circumference | 25.5 | 25.6 | 25.8 | 25.3 | 0.49 | 0.81 | 0.57 |
| Body mass index, $kg/m^2$ | 19.2 | 18.8 | 19.5 | 18.7 | 0.55 | 0.78 | 0.73 |
| Ponderal index, $kg/m^3$ | 67.2 | 65.1 | 67.9 | 66.3 | 2.03 | 0.99 | 0.88 |
| Body weight, kg | | | | | | | |
| At birth | 1.61 | 1.60 | 1.63 | 1.52 | 0.083 | 0.55 | 0.50 |
| 5 days post-farrowing | 2.38 | 2.37 | 2.45 | 2.22 | 0.126 | 0.49 | 0.36 |
| 16 days post-farrowing | 5.36 | 5.28 | 5.25 | 4.94 | 0.272 | 0.29 | 0.65 |
| Weaning | 7.69 | 7.54 | 7.26 | 7.36 | 0.348 | 0.41 | 0.71 |
| 1 week post-weaning | 7.82 | 7.69 | 7.42 | 7.48 | 0.371 | 0.55 | 0.92 |
| 2 week post-weaning | 8.93 | 9.17 | 8.71 | 8.93 | 0.453 | 0.82 | 0.99 |
| ADG, g/day | | | | | | | |
| Birth to 5 days post-farrowing | 154 | 154 | 160 | 137 | 12.6 | 0.44 | 0.34 |
| Birth to 16 days post-farrowing | 235 | 230 | 225 | 212 | 13.9 | 0.25 | 0.74 |
| Birth to weaning | 237 | 232 | 222 | 222 | 11.5 | 0.29 | 0.82 |
| Weaning to 2 weeks post-weaning | 86 | 116 | 103 | 113 | 17.3 | 0.38 | 0.52 |
| 1 week to 2 weeks post-weaning | 172 | 194 | 184 | 207 | 20.8 | 0.31 | 0.98 |
| Birth-2 week post-weaning | 185 | 191 | 180 | 184 | 9.9 | 0.73 | 0.90 |
| Feed intake, g/piglet | | | | | | | |
| 1 week pre-weaning | 182 | 186 | 157 | 189 | 24.5 | 0.95 | 0.55 |
| 1 week post-weaning | 753 | 883 | 760 | 786 | 121.0 | 0.96 | 0.65 |
| 2 weeks post-weaning | 1428 | 1638 | 1436 | 1600 | 144.0 | 0.63 | 0.87 |
| Post-weaning diarrhoea,% | | | | | | | |
| 1 week post-weaning | 26.1 | 29.3 | 27.0 | 29.6 | 2.47 | 0.47 | 0.77 |
| 2 weeks post-weaning | 17.4 | 17.2 | 12.8 | 22.2 | 2.82 | 0.44 | 0.05 |
| Days with diarrhoea, days | | | | | | | |
| 1 week post-weaning | 1.89 | 2.09 | 1.85 | 2.10 | 0.171 | 0.61 | 0.90 |
| 2 weeks post-weaning | 1.45 | 1.40 | 1.11 | 1.80 | 0.172 | 0.34 | 0.02 |

[1]T12 = Sow's lactation diet containing 12% of hemicelluloses; T11 = Sow's lactation diet containing 11% of hemicelluloses; T9 = Sow's lactation diet containing 9% of hemicelluloses; T7 = Sow's lactation diet containing 7% of hemicelluloses.

[2]Contrasts: L = Linear; Q = Quadratic.

**Table 4. Effect of decreasing hemicelluloses level in maternal diet on the performance of low birthweight piglets**

| | [1]Dietary Treatments | | | | SEM | [2]Contrasts | |
|---|---|---|---|---|---|---|---|
| | T12 | T11 | T9 | T7 | | *L* | *Q* |
| Body measurements at birth, cm | | | | | | | |
| Crown-to-rump length | 25.0 | 25.4 | 25.5 | 26.0 | 0.56 | 0.22 | 0.97 |
| Body circumference | 22.3 | 21.8 | 21.9 | 22.3 | 0.42 | 0.98 | 0.16 |
| Body mass index, $kg/m^2$ | 16.6 | 15.5 | 16.1 | 15.8 | 0.65 | 0.51 | 0.43 |
| Ponderal index, $kg/m^3$ | 66.6 | 61.4 | 63.6 | 61.7 | 3.22 | 0.37 | 0.54 |
| Body weight, kg | | | | | | | |
| At birth | 1.04 | 1.01 | 1.04 | 1.06 | 0.047 | 0.64 | 0.46 |
| 5 days post-farrowing | 1.61 | 1.59 | 1.58 | 1.54 | 0.095 | 0.53 | 0.86 |
| 16 days post-farrowing | 3.94 | 3.78 | 3.59 | 3.85 | 0.287 | 0.70 | 0.39 |
| Weaning | 5.86 | 5.73 | 5.42 | 6.55 | 0.468 | 0.38 | 0.12 |
| 1 week post-weaning | 5.92 | 5.96 | 5.56 | 6.95 | 0.498 | 0.20 | 0.12 |
| 2 week post-weaning | 6.55 | 6.66 | 6.43 | 8.35 | 0.545 | 0.02 | 0.06 |
| ADG, g/day | | | | | | | |
| Birth to 5 days post-farrowing | 113 | 118 | 104 | 91 | 14.1 | 0.14 | 0.43 |
| Birth to16 days post-farrowing | 181 | 173 | 158 | 173 | 16.7 | 0.57 | 0.41 |
| Birth to weaning | 192 | 184 | 171 | 201 | 16.3 | 0.83 | 0.18 |
| Weaning to 2 weeks post-weaning | 50 | 62 | 74 | 113 | 27.0 | 0.09 | 0.56 |
| 1 week to 2 weeks post-weaning | 91 | 103 | 125 | 187 | 27.0 | 0.01 | 0.25 |
| Birth to 2 weeks post-weaning | 141 | 143 | 135 | 177 | 11.5 | 0.04 | 0.05 |
| Post-weaning diarrhoea,% | | | | | | | |
| 1 week post-weaning | 19.8 | 34.1 | 16.4 | 20.8 | 10.50 | 0.69 | 0.50 |
| 2 weeks post-weaning | 36.4 | 16.7 | 6.5 | 5.2 | 8.31 | <0.01 | 0.35 |
| Days in diarrhoea, days | | | | | | | |
| 1 week post-weaning | 1.66 | 2.26 | 1.32 | 1.63 | 0.502 | 0.56 | 0.71 |
| 2 weeks post-weaning | 2.36 | 1.22 | 0.55 | 0.87 | 0.512 | <0.01 | 0.07 |

[1]T12 = Sow's lactation diet containing 12% of hemicelluloses; T11 = Sow's lactation diet containing 11% of hemicelluloses; T9 = Sow's lactation diet containing 9% of hemicelluloses; T7 = Sow's lactation diet containing 7% hemicellulose.

[2]Contrasts: *L* = Linear; *Q* = Quadratic.

***Milk Composition***

Throughout lactation, no dietary treatment and sampling day interaction was found (data not shown). At days 3 and 17 of lactation, DM, ash, protein and somatic cell count, as well as milk yield estimated from farrowing to day 3 and from day 4 to day 17 of lactation, were similar among dietary treatments (Table 5). With a decreasing HC level, milk lactose content linearly decreased ($P < 0.01$). Regarding mineral levels in the sow milk, calcium, phosphorus, sodium, magnesium and zinc contents remained similar among experimental treatments, whereas the copper content linearly increased ($P = 0.02$) with decreasing HC content in the maternal diet. Excluding the linear increase ($P = 0.04$) in the threonine level and the quadratic increase ($P = 0.04$) in the monounsaturated fatty acid portion, decreasing HC level in the maternal diet had no impact on the amino acid and fatty acid profiles. Regardless of the dietary treatments, somatic cell counts did not differ between the sampling days. However, the sampling day influenced protein, mineral and lactose contents, as well as milk yield. Between days 3 and 17 of lactation, protein, phosphorus, potassium and zinc contents decreased ($P \leq 0.05$), whereas lactose and calcium contents and milk yield increased ($P \leq 0.05$). Furthermore, histidine, leucine, isoleucine, phenylalanine, threonine, tryptophan, tyrosine, valine, alanine, aspartic acid and serine decreased ($P \leq 0.05$), whereas glutamate and proline increased ($P \leq 0.05$) between days 3 and 17. The fatty acid profile in milk changed during lactation. Monounsaturated and polyunsaturated fatty acid portions decreased ($P \leq 0.05$) and saturated fatty acid content increased ($P \leq 0.05$) from day 3 to day 17. More precisely, the portions of C18:0, C18:1n-9, C18:2n-6, C18:3n-6, C18:3n-3, C20:4n-6, C20:5n-3 and C22:5n-3 decreased ($P \leq 0.05$), whereas C16:0 level increased ($P \leq 0.05$) between days 3 and 17.

**Table 5. Effect of decreasing hemicellulose level in sow's lactation diet on gross composition, mineral content, amino acid profile and fatty acid profile of milk**

| | [1]Dietary Treatments | | | | | [2]Contrasts | | [3]Stage of lactation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | T12 | T11 | T9 | T7 | SEM | *L* | *Q* | d3 | d17 | SEM | *P*-value |
| Milk yield, kg/day | 9.66 | 9.90 | 9.39 | 8.80 | 0.76 | 0.81 | 0.76 | 7.03 | 1.85 | 0.41 | <0.01 |
| Gross chemical composition | | | | | | | | | | | |
| Dry matter, % | 19.5 | 20.7 | 19.9 | 20.6 | 0.60 | 0.25 | 0.49 | 20.7 | 19.7 | 0.40 | 0.06 |
| Total protein, % | 5.86 | 5.82 | 5.84 | 6.07 | 0.153 | 0.48 | 0.34 | 6.40 | 5.40 | 0.091 | <0.01 |
| Fat, % | 7.50 | 8.65 | 8.07 | 8.69 | 0.533 | 0.15 | 0.38 | 8.50 | 7.96 | 0.364 | 0.27 |
| Lactose, % | 5.17 | 4.99 | 4.92 | 4.77 | 0.110 | 0.01 | 0.76 | 4.56 | 5.37 | 0.068 | <0.01 |
| Ash,% | 0.86 | 0.86 | 0.88 | 0.85 | 0.150 | 0.29 | 0.89 | 0.89 | 0.83 | 0.098 | <0.01 |
| Somatic cells, log $10^3$ cells/ml | 6.99 | 6.92 | 7.40 | 7.71 | 0.325 | 0.18 | 0.41 | 7.40 | 7.11 | 0.248 | 0.93 |
| Gross energy, MJ/kg | 5.14 | 5.70 | 5.43 | 5.70 | 0.230 | 0.10 | 0.30 | 5.65 | 5.34 | 0.162 | 0.72 |
| Minerals | | | | | | | | | | | |
| Calcium, g/kg | 1.91 | 1.98 | 2.02 | 1.99 | 0.051 | 0.97 | 0.94 | 1.88 | 2.07 | 0.033 | <0.01 |
| Phosphorus, g/kg | 1.57 | 1.58 | 1.57 | 1.53 | 0.026 | 0.09 | 0.63 | 1.61 | 1.52 | 0.017 | <0.01 |
| Potassium, g/kg | 1.11 | 1.10 | 1.11 | 1.05 | 0.028 | 0.07 | 0.24 | 1.29 | 0.90 | 0.019 | <0.01 |
| Sodium, g/kg | 0.37 | 0.35 | 0.35 | 0.34 | 0.016 | 0.21 | 0.89 | 0.36 | 0.34 | 0.011 | 0.93 |
| Magnesium, g/kg | 0.10 | 0.11 | 0.11 | 0.11 | 0.003 | 0.42 | 0.09 | 0.11 | 0.11 | 0.002 | 0.57 |
| Copper, mg/kg | 1.37 | 1.45 | 1.51 | 1.76 | 0.135 | 0.02 | 0.28 | 1.68 | 1.37 | 0.085 | 0.67 |
| Zinc, mg/kg | 6.04 | 6.64 | 6.02 | 5.44 | 0.363 | 0.16 | 0.07 | 6.38 | 5.69 | 0.213 | <0.01 |
| Amino acids, % of total protein | | | | | | | | | | | |
| Alanine | 3.28 | 3.29 | 3.33 | 3.35 | 0.025 | 0.21 | 0.46 | 3.41 | 3.21 | 0.017 | <0.01 |
| Arginine | 4.57 | 4.62 | 4.68 | 4.67 | 0.029 | 0.13 | 0.99 | 4.72 | 4.55 | 0.020 | <0.01 |
| Aspartic acid | 7.70 | 7.68 | 7.75 | 7.74 | 0.035 | 0.78 | 0.29 | 7.83 | 7.61 | 0.025 | <0.01 |
| Cysteine | 1.40 | 1.39 | 1.39 | 1.42 | 0.015 | 0.15 | 0.10 | 1.44 | 1.36 | 0.010 | <0.01 |
| Glutamate | 17.8 | 17.6 | 17.8 | 17.6 | 0.16 | 0.29 | 0.99 | 17.5 | 17.9 | 0.11 | <0.01 |
| Glycine | 2.98 | 3.02 | 3.12 | 3.05 | 0.030 | 0.10 | 0.40 | 3.06 | 3.03 | 0.019 | 0.15 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Histidine | 2.53 | 2.53 | 2.53 | 2.56 | 0.015 | 0.85 | 0.31 | 2.56 | 2.51 | 0.009 | <0.01 |
| Isoleucine | 3.85 | 3.80 | 3.80 | 3.83 | 0.039 | 0.36 | 0.53 | 3.84 | 3.80 | 0.022 | 0.05 |
| Leucine | 8.03 | 8.12 | 8.02 | 8.15 | 0.049 | 0.74 | 0.83 | 8.18 | 7.99 | 0.030 | <0.01 |
| Lysine | 6.86 | 6.79 | 6.82 | 6.86 | 0.049 | 0.61 | 0.36 | 6.85 | 6.82 | 0.029 | 0.22 |
| Methionine | 1.74 | 1.72 | 1.71 | 1.71 | 0.014 | 0.10 | 0.68 | 1.72 | 1.72 | 0.008 | 0.52 |
| Phenylalanine | 3.86 | 3.85 | 3.87 | 3.92 | 0.026 | 0.17 | 0.13 | 3.92 | 3.83 | 0.017 | <0.01 |
| Proline | 10.2 | 10.3 | 10.4 | 10.2 | 0.11 | 0.37 | 0.15 | 10.1 | 10.5 | 0.07 | <0.01 |
| Serine | 4.70 | 4.66 | 4.73 | 4.76 | 0.047 | 0.15 | 0.39 | 4.75 | 4.67 | 0.030 | 0.02 |
| Threonine | 3.88 | 3.88 | 3.90 | 3.98 | 0.036 | 0.04 | 0.19 | 3.99 | 3.83 | 0.023 | <0.01 |
| Tryptophan | 1.18 | 1.18 | 1.21 | 1.20 | 0.017 | 0.17 | 0.94 | 1.23 | 1.15 | 0.011 | <0.01 |
| Tyrosine | 4.02 | 3.97 | 3.99 | 4.05 | 0.050 | 0.43 | 0.20 | 4.05 | 3.96 | 0.028 | <0.01 |
| Valine | 5.16 | 5.21 | 5.20 | 5.26 | 0.039 | 0.17 | 0.98 | 5.30 | 5.12 | 0.025 | <0.01 |
| Fatty acids, % of total fatty acids | | | | | | | | | | | |
| C16:0 | 27.2 | 27.4 | 26.4 | 27.8 | 0.70 | 0.52 | 0.38 | 24.9 | 29.5 | 0.48 | <0.01 |
| C18:0 | 4.29 | 4.43 | 4.33 | 4.41 | 0.143 | 0.70 | 0.70 | 4.78 | 3.95 | 0.089 | <0.01 |
| C18:1n-9 | 35.3 | 36.1 | 35.8 | 34.8 | 0.83 | 0.51 | 0.38 | 37.2 | 33.8 | 0.57 | <0.01 |
| C18:2n-6 | 11.45 | 9.63 | 12.08 | 11.74 | 0.412 | 0.09 | 0.09 | 12.20 | 10.30 | 0.245 | <0.01 |
| C18:3n-6 | 0.14 | 0.12 | 0.15 | 0.13 | 0.012 | 0.93 | 0.87 | 0.20 | 0.08 | 0.008 | <0.01 |
| C18:3n-3 | 1.08 | 1.12 | 1.16 | 1.32 | 0.057 | 0.06 | 0.53 | 1.25 | 1.09 | 0.036 | <0.01 |
| C20:3n-3 | 0.11 | 0.11 | 0.11 | 0.09 | 0.010 | 0.76 | 0.48 | 0.11 | 0.10 | 0.006 | 0.06 |
| C20:4n-6 | 0.52 | 0.50 | 0.55 | 0.55 | 0.022 | 0.16 | 0.53 | 0.65 | 0.41 | 0.014 | <0.01 |
| C20:5n-3 | 0.09 | 0.09 | 0.08 | 0.08 | 0.006 | 0.55 | 0.74 | 0.09 | 0.07 | 0.003 | <0.01 |
| C22:5n-3 | 0.23 | 0.22 | 0.21 | 0.22 | 0.018 | 0.77 | 0.61 | 0.26 | 0.18 | 0.010 | <0.01 |
| *n*-3[4] | 1.75 | 1.59 | 1.50 | 1.48 | 0.082 | 0.19 | 0.60 | 1.72 | 1.44 | 0.051 | <0.01 |
| *n*-6[5] | 12.1 | 10.3 | 12.8 | 12.4 | 0.43 | 0.09 | 0.10 | 13.0 | 10.8 | 0.26 | <0.01 |
| Saturated | 36.1 | 36.4 | 35.3 | 37.1 | 0.76 | 0.57 | 0.40 | 33.8 | 38.6 | 0.52 | <0.01 |
| Mono-unsaturated | 49.1 | 50.8 | 49.5 | 48.1 | 0.61 | 0.71 | 0.04 | 50.4 | 48.3 | 0.42 | <0.01 |
| Poly-unsaturated | 14.8 | 12.8 | 15.2 | 14.9 | 0.53 | 0.22 | 0.14 | 15.7 | 13.1 | 0.32 | <0.01 |

[1]T12 = Sow's lactation diet containing 12% of hemicelluloses; T11 = Sow's lactation diet containing 11% of hemicelluloses; T9 = Sow's lactation diet containing 9% of hemicelluloses; T7 = Sow's lactation diet containing 7% of hemicelluloses.

[2]Contrasts: *L* = Linear; *Q* = Quadratic.

[3] Days: d3 = Day 3 of lactation; d17 = Day 17 of lactation;

[4]*n*-3: sum of C18:3n-3, C20:3n-3, C20:5n-3, C22:5n-3.

[5]*n*-6: sum of C18:2n-6, C18:3n-6 and C20:4n-6.

### *Volatile fatty acid concentrations in milk*

The VFA concentration and the proportion of butyrate linearly increased (*P* < 0.01; Table 6) with decreased HC content in the maternal diet, resulting in an increased in total VFA by 25% and butyrate proportion by 60%. Regardless of the dietary treatment, total VFA concentration decreased (*P* ≤ 0.05) by 71% between days 3 and 17. The proportion of methanoate increased (*P* < 0.01), and the proportion of acetate decreased (*P* < 0.01) between days 3 and 17, whereas the levels of propionate, isobutyrate, butyrate and isovalerate remained unchanged.

**Table 6. Effect of decreasing hemicellulose levels in sow's lactation diet on the volatile fatty acid profile of milk**

| | [1]Dietary Treatments | | | | | [2]Contrasts | | [3]Stage of lactation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | T12 | T11 | T9 | T7 | SEM | *L* | *Q* | d3 | d17 | SEM | *P*-value |
| Total volatile fatty acids, mmol/kg | 3.07 | 3.58 | 3.60 | 3.86 | 0.28 | 0.03 | 0.60 | 4.12 | 2.94 | 0.19 | <0.01 |
| Proportion of individual VFA, % | | | | | | | | | | | |
| Methanoate | 9.41 | 9.50 | 9.38 | 9.93 | 0.287 | 0.94 | 0.28 | 9.16 | 9.95 | 0.187 | <0.01 |
| Acetate | 88.90 | 89.00 | 88.90 | 88.30 | 0.353 | 0.31 | 0.17 | 89.21 | 88.36 | 0.220 | <0.01 |
| Propionate | 0.30 | 0.30 | 0.25 | 0.20 | 0.041 | 0.19 | 0.84 | 0.25 | 0.28 | 0.026 | 0.29 |
| Isobutyrate | 0.04 | 0.04 | 0.05 | 0.03 | 0.007 | 0.86 | 0.79 | 0.04 | 0.05 | 0.004 | 0.17 |
| Butyrate | 0.53 | 0.60 | 0.75 | 0.86 | 0.153 | <0.01 | 0.64 | 0.68 | 0.69 | 0.104 | 0.29 |
| Isovalerate | 0.76 | 0.55 | 0.57 | 0.57 | 0.080 | 0.80 | 0.21 | 0.61 | 0.61 | 0.043 | 0.81 |

[1]T12 = Sow's lactation diet containing 12% of hemicelluloses; T11 = Sow's lactation diet containing 11% of hemicelluloses; T9 = Sow's lactation diet containing 9% of hemicelluloses; T7 = Sow's lactation diet containing 7% of hemicelluloses.

[2]Contrasts: *L* = Linear; *Q* = Quadratic

[3]d3 = Day 3 of lactation; d17 = Day 17 of lactation

## Discussion

### *Effect of decreasing the level of hemicelluloses on sows' performance*

Excluding fibre intake, the sow's performances were not affected by dietary HC. As expected, due to similar feed intake during the pre-farrowing and lactation periods, decreasing the level of HC also reduced the intake of the low-molecular-weight DF and SDF fractions. Renteria-Flores et al. (2008) found that increasing the SDF level in the gestation diet increased BW loss during lactation. However, the adverse effects may be related to the inclusion level of SDF. Similar to the present study, Li et al. (2019b) found no effect on sow's performance when the SDF level was decreased from 38.7 g/kg to 17.7 g/kg in the gestation diet during the whole gestation period. In addition, considerably high SDF intake can negatively affect litter performance. Indeed, Liu et al. (2020) reported that from day 90 of gestation to farrowing, a daily intake of 215 g of SDF (SDF: 45.7 g/kg as fed), compared with 138 g/day (29.7 g/kg as fed) and 96 g/day (17.8 g/kg), decreases the number of piglets and litter weight at weaning. In the present study, sows received experimental diets between 133 g/day and 83 g/day of SDF only from day 110 of gestation onwards. This setup can explain the lack of differences in these traits between the dietary treatments.

### *Effect of decreasing hemicelluloses levels on milk composition and milk VFA profile*

Milk yield and composition play a crucial role in the growth of suckling piglets to reach an adequate weaning weight. In the present study, decreasing the level of HC in the maternal diet affected milk composition but did not affect milk yield. Furthermore, lactose content decreased, whereas copper and threonine proportions increased with decreased HC level. A previous study showed that glucose, glycerol and other glucose precursors play an important role in the synthesis of lactose in sow's milk (Boyd et al., 1995). Moreover, a recent study showed that a 3:1 ratio of IDF to SDF increases the fermentability of organic matter in the small intestine (Hoogeveen et al., 2021). As decreasing the level of HC in sow's diet, increased the IDF to SDF ratio, the fermentability of organic matter might have decreased. Therefore, a higher level of HC could be related to the higher fermentability of the organic matter in the small intestine. Given that HC contains various polysaccharides, sows possibly use HC for the synthesis of lactose in milk. Given the osmotic power of lactose, milk yield may drop together with lactose as the HC level decreases (Costa et al., 2019). Surprisingly, milk yield only decreased numerically, and this result could be due to the differences in lactose concentration between the experimental groups, which were not sufficiently large to affect milk yield. A further interest in the present study is the linear increase in copper in milk with a decreased HC level. Copper is an essential microelement for animals, with many biological functions, including iron metabolism, immunity, protection from oxidative stress and improvement in the activity of digestive enzymes (Huang et al., 2015). The milk concentration of copper is affected by the source of the micromineral (Peters et al., 2010). However, as the same micromineral source was used among the four dietary treatments, the mechanism underlying the increase in copper concentration remains unclear. Similarly, with decreased HC levels in the diet, the proportion of threonine in the milk increased. This effect remains unclear, as the calculated digestible threonine levels were similar between the T12 and T7 diets. Besides a similar DF content, hypothetically, decreasing the HC level using several DF sources may affect the fermentation patterns in the gut, namely, the concentration and proportion of VFA. As VFA can be absorbed, transported through the blood and finally reach the mammary glands, modifications in the milk composition are expected (Tian et al., 2020). Decrease in HC level increased total VFA concentration and butyrate proportion in milk. Zhao et al. (2019) showed a positive correlation between VFA concentration in pig's ileum and decreased HC level. Given that sows can ferment DFs better than growing pigs, a similar phenomenon may have occurred in the ileum of sows fed with a low HC level (Noblet and Le Goff, 2001). Furthermore, this effect on VFA in milk may also be due to differences in the intake of other DF fractions. As previously mentioned, decreasing HC level concomitantly increased ADF intake and decreased SDF intake. A positive correlation was reported between the ADF level in pig's diet and butyrate concentration in the faeces (Zhao et al., 2019). In the present study, hypothetically, increased ADF intake in sows fed with decreasing level of HC might have increased the butyrate proportion in the faeces and then in the milk. Compared with IDF, SDF is rapidly fermented by bacteria, thereby enhancing the production of VFA (Jha and Berrocoso, 2015). Therefore, with decreased SDF intake, VFA production should be lowered. However, the present study showed that this concept was not evident and confirmed the importance of the source of DF, as reported by some authors (Theil et al., 2014). Therefore, to understand the effects of DF on milk composition, different fractions of DF, including HC and ADF contents, must be considered.

### *Effects of the lactation diet on piglets' performance*

In the present study, modifying the level of HC in the maternal diet did not enhance litter performance. This result is consistent with the results of Loisel et al. (2013), which showed that modifying the maternal diet is easier to positively affect the performances of L-BtW piglets than the performance of the litter overall. Therefore, decreasing the

HC level improved post-weaning performance and reduced the occurrence of diarrhoea in the L-BtW piglets. By contrast, why the performance of N-BtW was unaffected by the HC level even though the occurrence of diarrhoea increased in this group remains unclear. The L-BtW piglets usually exhibit poor performances, such as a high mortality rate and low ADG, which represents high economic costs for farmers due to reduced slaughter weight and increased occupancy of the stables (López-Vergé et al., 2018). Girard et al. (2021) highlighted the importance of early-life interventions to improve the post-weaning development and health of this sub-population of piglets. Therefore, the beneficial effects observed in the present study may be related to the combination of an increased relative abundance of butyrate, threonine and copper and to an increased concentration of total VFA in milk. Indeed, butyrate, due to its recognised role in gut health, could have been useful in increasing gut impermeability, alleviating diarrhoea in L-BtW piglets during the second week post-weaning (Feng et al., 2018). In addition, given that piglets are highly susceptible to intestinal bacterial disorders during the post-weaning period, increasing threonine and copper proportions in the milk in the pre-weaning period can help accelerate the gut maturation of those piglets (Lalles et al., 2009). Threonine definitely plays a critical role in the regulation of intestinal mucosal integrity, as it is required for the production of mucins and immunoglobulins, improving the physical protection from the attachment of microbes to the mucosal surface (Van Klinken et al., 1995). By contrast, copper can help against pathogenic bacteria because of its bacteriostatic properties, which affect the community structure of microorganisms in the caecum and colon (Højberg et al., 2005). A lower relative abundance of *Alistipes*, *Lachnospiraceae*, *Ruminococcaceae* and *Prevotellaceae* has been reported in the colon and ileum of L-BtW piglets compared with N-BtW piglets (Li et al., 2019a). These genera enhance gut health and immune functions in the host (Den Besten et al., 2013). Given that colostrum and mature milk are key components in shaping piglet microbiota (Trevisi et al., 2021), the modification of milk composition induced by decreased HC level in the sow diet might have changed the gut microbiota of L-BtW piglets and improved their health and growth.

### *Effect of lactation stage on milk composition*

Sow's milk composition is strongly affected by changes throughout the lactation period. Colostrum (0–24 h after parturition) and transitional milk (48–72 h after parturition) contain higher amounts of lipids, protein and dry matter compared with mature milk (from day 10 of lactation) (Csapó et al., 1996). In the present study, the passage from transitional milk to mature milk was characterised by a decrease in protein and ash contents and an increase in lactose content. Nevertheless, the contents of fat, dry matter and gross energy decreased only numerically from day 3 to day 17. Indeed, in the present experiment, the lack of statistical differences on those traits could be due to the differences between the sampling days, which were not large enough to affect dry matter, fat and gross energy contents in the sow's milk. Similarly, the decrease in amino acid proportion follows the same trend as protein content, except for glycine, lysine and methionine, which remained stable over lactation, and for glutamate and proline, which increased from day 3 to day 17. Therefore, the high level of amino acids in transitional milk reflects the protein level, mainly because of the high content of immunoglobulins (Klobasa et al., 1987). The mineral content and fatty acid profile were also affected by the stage of lactation. Calcium and phosphorus play a key role in improving piglet's growth (Hu et al., 2019). These changes are consistent with a previous study (Csapó et al., 1996) that also reported an increase in the calcium level and a decrease in the potassium and zinc levels from transitional milk to mature milk.

The present experiment also showed a decrease in phosphorus content. The reason for the decrease in the phosphorus concentration over lactation remains unclear but might be related to a dilution effect, as it follows the numerical decrease in dry matter. When expressed per kilogram of dry matter, the phosphorus concentration was similar between days 3 and 17. Moreover, from transitional milk to mature milk, the decrease in the proportion of mono- and polyunsaturated fatty acids and the increase in the proportion of saturated fatty acids are related to changes in the proportion of individual fatty acids. The increase in C16:0 proportion and decrease in the proportions of C18:0, C18:1n-9, C18:2n-6, C18:3n-6, C18:3n-3, C20:4n-6 and C20:5n-3 observed in the present study have already been described in a previous study (Hu et al., 2019). Furthermore, Hu et al. (2019) reported a positive correlation between calcium and C16:0 fatty acid. Indeed, long-chain saturated fatty acids can form calcium salts in the piglet's intestine, which can improve dry matter digestibility and enhance growth performance (Kluge et al., 2006). However, the mechanism by which calcium affects the synthesis of C16:0 remains unknown.

In conclusion, as shown in the present study, when the DF level is the same, feeding lactating sows with a decreasing HC level can positively affect the milk composition and offspring development of L-BtW piglets. As HC content decreased, the growth performance of the L-BtW piglets improved after weaning, and the occurrence of diarrhoea decreased, particularly in the second week post-weaning. Moreover, it increased the proportion of butyrate, copper and threonine and increased the VFA concentration in the milk. Therefore, this study highlighted the importance of the maternal diet in lactation to positively affect the development and health of L-BtW piglets in the post-weaning period.

## Ethics approval

The experiment was conducted in accordance with the Swiss Guidelines for Animal Welfare, and the Swiss Cantonal Committee for Animal Care and Use approved all procedures involving animals (approval number: 2019_25_FR).

## Data accessibility

The data that support the findings of this study are publicly available in Zenodo (https://doi.org/10.5281/zenodo.5814624).


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## Author contributions

Francesco Palumbo and Marion Girard validated the data and carried out the main statistical analyses. Marion Girard and Giuseppe Bee conceived the study design and secured substantial funding. Francesco Palumbo and Marion Girard performed the animal experiment, recorded the data and collected and processed the milk samples. Marion Girard, Francesco Palumbo, Giuseppe Bee and Paolo Trevisi supervised analyses and drafted and critically reviewed the manuscript. All authors read and approved the final manuscript.


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**Declaration of interest**

The authors declare they have no conflict of interest relating to the content of this article.

**Supplementary materials**

The Supplementary Table S1 and the statistical codes used can be found in the Supplementary Materials.

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**Supplementary Materials**

**Title:** Decreasing the level of hemicelluloses in sow's lactation diet affects milk composition and post-weaning performances of low birthweight piglets.

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**Supplementary Table S1. Effect of decreasing hemicelluloses levels in maternal diet on the performances of normal birthweight piglets**

| | [1]Dietary Treatments | | | | | [2]Contrasts | |
|---|---|---|---|---|---|---|---|
| | T12 | T11 | T9 | T7 | SEM | L | Q |
| Body measurements at birth, cm | | | | | | | |
| Crown to rump length | 29.4 | 29.5 | 29.1 | 28.8 | 0.46 | 0.28 | 0.60 |
| Body circumference | 26.1 | 26.1 | 26.2 | 25.7 | 0.41 | 0.53 | 0.48 |
| Body mass index, $kg/m^2$ | 19.7 | 19.4 | 20.0 | 19.2 | 0.54 | 0.69 | 0.63 |
| Ponderal index, $kg/m^3$ | 67.6 | 65.8 | 69.0 | 66.9 | 2.16 | 0.90 | 0.93 |
| Body weight, kg | | | | | | | |
| At birth | 1.70 | 1.69 | 1.70 | 1.59 | 0.070 | 0.29 | 0.44 |
| 5 days post-farrowing | 2.52 | 2.49 | 2.52 | 2.32 | 0.112 | 0.26 | 0.39 |
| 16 days post-farrowing | 5.64 | 5.53 | 5.38 | 5.06 | 0.252 | 0.10 | 0.65 |
| Weaning | 8.08 | 7.86 | 7.43 | 7.45 | 0.320 | 0.12 | 0.72 |
| 1 week post-weaning | 8.13 | 8.04 | 7.61 | 7.55 | 0.341 | 0.21 | 0.81 |
| 2 weeks post-weaning | 9.41 | 9.56 | 8.91 | 8.99 | 0.422 | 0.32 | 0.94 |
| ADG, g/d | | | | | | | |
| Birth-5 days post-farrowing | 162 | 160 | 164 | 144 | 12.5 | 0.38 | 0.44 |
| Birth-16 days post-farrowing | 246 | 240 | 230 | 216 | 13.5 | 0.11 | 0.76 |
| Birth- Weaning | 248 | 240 | 227 | 224 | 11.1 | 0.10 | 0.83 |
| Weaning-2 weeks post-weaning | 90 | 122 | 105 | 111 | 17.1 | 0.56 | 0.41 |
| Birth-2 week post-weaning | 194 | 198 | 183 | 184 | 9.6 | 0.29 | 0.85 |
| Post-weaning diarrhoea,% | | | | | | | |
| 1 week post-weaning | 26.1 | 28.4 | 27.4 | 30.7 | 2.82 | 0.32 | 0.86 |
| 2 weeks post-weaning | 13.1 | 17.2 | 13.5 | 24.6 | 3.15 | 0.02 | 0.23 |
| Days in diarrhoea, d | | | | | | | |
| 1 week post-weaning | 1.92 | 2.05 | 1.96 | 2.17 | 0.189 | 0.44 | 0.81 |
| 2 weeks post-weaning | 1.16 | 1.43 | 1.20 | 1.96 | 0.187 | 0.01 | 0.17 |

[1]T12 = Sow's lactation diet containing 12% of hemicelluloses; T11 = Sow's lactation diet containing 11% of hemicelluloses; T9 = Sow's lactation diet containing 9% of hemicelluloses; T7 = Sow's lactation diet containing 7% of hemicelluloses.

[2]Contrasts: L = Linear; Q = Quadratic

**R Codes used for the statistical model:**

<u>Sow performance, litter performance, piglet feed intake and days with diarrhoea</u>

```
contrasts(dataset$treatment)<- contr.poly(nlevels(dataset$treatment))

model<-lm (X ~ treatment + farrowing batch, data=dataset, na.action = na.omit)
anova(model)
summary (modelparity)
lsmeans <- lsmeans (model, ~ treatment)
print (cld (lsmeans, sort=TRUE, Letters=c("abcdefghijklmnopqrstuvwxyz"),
adjust="Tukey"))
```

<u>Piglets ‘individual performance</u>

```
contrasts(dataset$treatment)<- contr.poly(nlevels(dataset$treatment))

model<-lme(X ~ treatment + farrowing batch, random = ~ 1 | sow, data=dataset,
na.action = na.omit)
summary(model)
Anova(model, type="III")
lsmeans <- lsmeans (model, ~ treatment)
print (cld (lsmeans, sort=TRUE, Letters=c("abcdefghijklmnopqrstuvwxyz"),
adjust="Tukey"))
```

<u>Milk composition and VFA</u>

```
contrasts(dataset$treatment)<- contr.poly(nlevels(dataset$treatment))

model<-lme(X ~ treatment* sampling day + farrowing batch, random=~1|sow,
data=dataset, na.action = na.omit)
summary(model)
Anova(model, type="III")
lsmeans1 <- lsmeans (model, ~ treatment)
```

```
lsmeans2 <- lsmeans (model, ~ sampling day)
print (cld (lsmeans1, sort=TRUE, Letters=c("abcdefghijklmnopqrstuvwxyz"),
adjust="Tukey"))
print (cld (lsmeans2, sort=TRUE, Letters=c("abcdefghijklmnopqrstuvwxyz"),
adjust="Tukey"))
```

Diarrhea percentage

```
contrasts(dataset$treatment)<- contr.poly(nlevels(dataset$treatment))

model <- glmmPQL (X ~ treatment+farrowing batch+day, data=dataset, random = ~ 1
| id, family = binomial(link = logit), correlation=corAR1(form=~as.numeric(day)|id,
fixed=FALSE))
summary(model)
Anova(model, type="II")

lsmeans <- lsmeans(model, ~ treatment, transform ="response")
print(cld(lsm.1, sort=TRUE, Letters=c("abcdefghijklmnopqrstuvwxyz"),
adjust="Tukey"))
```