Review article
Journal of Central European Agriculture, 2021, 22(1), p.54-65
DOI: /10.5513/JCEA01/22.1.2927

# Selected feed additives used in pig nutrition

## Wybrane dodatki paszowe stosowane w żywieniu świń

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Received: June 8, 2020; accepted: October 30, 2020

## ABSTRACT

The paper provides an overview of the knowledge of the options of the use of selected feed additives in the feeding of sows and young pigs. Feed enzymes, organic acids, probiotics, prebiotics and phytobiotics are the most commonly used feed additives for these technology groups. Nowadays, in pig breeding and farming, it is not possible to achieve high production performance in the herd without the use of specialised feed additives. They are added to the feed ration always in small quantities, and the effects of their use are often clearly noticeable. They improve the flavour and digestibility of the feed, and thereby have a favourable effect on feed intake, piglets weight gain and sows milk yield, boost pig immunity and displace pathogens from the gastrointestinal system, stimulating the growth and development of the beneficial bacterial microflora. Fed to lactating sows, they have a positive effect not only on the sows, but above all on the growth and development of their litters. This allows maximising the weaning weight of piglets and improving their health and weight gain at further fattening stages. All this contributes to improved production performance and should encourage breeders to enrich pig feed with appropriate specialised feed additives.

**Keywords:** enzyme, probiotic, organic acids, herbs, sows, young pigs

## STRESZCZENIE

W pracy przedstawiono przegląd wiedzy na temat możliwości wykorzystania wybranych dodatków paszowych w żywieniu loch i młodych świń. Enzymy paszowe, kwasy organiczne, probiotyki, prebiotyki i fitobiotyki to najczęściej stosowane dodatki paszowe dla tych grup technologicznych. Współcześnie w chowie i hodowli trzody chlewnej osiągnięcie wysokich wyników produkcyjnych w stadzie nie jest możliwe bez zastosowania specjalistycznych dodatków paszowych. Dodawane są do mieszanki paszowej zawsze w małych ilościach, a efekty ich stosowania są często bardzo wyraźnie zauważalne. Poprawiają smak i strawność paszy przez co korzystnie wpływają na jej pobranie, przyrosty prosiąt i mleczność loch, wzmacniają odporność świń oraz wypierają patogeny z układu pokarmowego, stymulując wzrost i rozwój korzystnej mikroflory bakteryjnej. Podawane dla loch karmiących pozytywnie oddziaływają nie tylko na maciory, ale przede wszystkim na wzrost i rozwój ich miotów. Dzięki temu można uzyskać wyższą masę odsadzeniową prosiąt oraz lepszą zdrowotność i przyrosty w dalszym tuczu. Wszystko to przekłada się na poprawę wyników produkcji i powinno skłaniać hodowców do wzbogacania pasz dla świń w odpowiednie specjalistyczne dodatki paszowe.

**Słowa kluczowe:** enzym, probiotyk, kwasy organiczne, zioła, lochy, młode świnie

## INTRODUCTION

The current pig breeding and farming is based on maintaining selected hybrid breeds whose genetic potential can be revealed under appropriate conditions of well-being and precise nutrition. In order to achieve this objective, from the point of view of pig nutrition, it is necessary to enrich feed rations with specialised feed additives. Feed additives used in pig nutrition include, for instance: feed enzymes, organic acids, herbs and their extracts and probiotics (Balasubramanian et al., 2016; Tactacan et al. 2016; Chen et al., 2016; Min et al., 2019; Park et al., 2020). Feed additives introduced into feed rations can improve their nutritional value, replenish nutrient deficiencies, support digestive processes, have a beneficial effect on the development of the intestinal microflora, among other ways, by maintaining biological equilibrium in the gastrointestinal system (Hanczakowska et al., 2012; Bedford et al., 2014; Devi et al., 2016). This is extremely important, because monogastric animals, including pigs, do not have the proventriculus, so digesting fibre and its fractions is impossible or very difficult for them. In addition, they are more sensitive to the presence of the anti-nutrients in feed. Studies (De Lange et al., 2010; Hanczakowska et al., 2011; Tactacan et al., 2016; Min et al., 2019; Park et al., 2020) show that the introduction of feed enzymes into feed rations for pigs, and in particular for piglets and weaners, contributes to improving digestibility and improved feed conversion rate. This is probably due to increased enzymatic activity in the gastrointestinal tract of animals, which also contributes to stabilising the population of microorganisms. Bernardez et al. (2008) and Slivinska and Lukashchuk (2018) argue that the microflora of the gastrointestinal tract in piglets and weaners, and thus their health, are effectively stimulated by probiotics that can be additionally combined with prebiotics. These additives also help reduce the use of antibiotics, thereby decreasing the costs of medical treatment and minimising pig deaths (Bedford et al. 2014; Link et al., 2016). In addition, probiotics increase the rate of feed conversion, thus improving the weight gain of animals (Giang et al., 2011; Zhang et al., 2020). Numerous studies (Liu et al., 2014; Balasubramanian et al., 2016a; Devi et al., 2016; Long et. al., 2018) have shown that the use of organic acids not only in the nutrition of piglets, but also sows, during the periparturient period and postpartum period has a beneficial effect on the conversion and digestibility of feed by sows and on the health of their offspring by reducing the episodes of diarrhoea and deaths, which consequently improves the weight gain of piglets. Another popular feed additive is herbs and phytobiotics, although the effectiveness of their use depends on a number of factors such as, for instance, the species, forms of administration or taste preferences in pigs (Hanczakowska and Świątkiewicz, 2012; Costa et al., 2013; Lipiński et al., 2014; Hossain et al., 2015). A multitude of specialised feed additives for each pig production group is available for sale. Similarly, there are multiple advantages of using them, but the effectiveness of additives depends on their skilful choice and introduction into the feed ration. The aim of the paper is to present the effects of using specialised feed additives in the nutrition of sows and growing pigs.

## FEED ENZYMES

Feed enzymes are the derivatives of the fermentation process involving moulds, fungi and bacteria,such as for example: *Aspergillus* ssp., *Penicillium* ssp., *Hurnicola* ssp. and *Bacillus* ssp. Feed enzymes can be endogenous and exogenous. Endogenous enzymes occur in the body, and include: proteases breaking down proteins into peptides and amino acids, amylases breaking down starch into dextrins and maltose and glucose, and lipases breaking down lipids into triacylglycerols and fatty acids. They are normally used as additives for young animals exhibiting a low activity of such enzymes. Another type of feed enzymes is exogenous enzymes, including: carbohydrolases and phytases. Carbohydroxylases breaking down the components of dietary fibre include: cellulases breaking down cellulose into β-1-4 polysaccharides, β-glucanase breaking down β-glucans into oligosaccharides and glucose, xylanases breaking down pentosans into xylose and xylobiose as well as hemicellulase and pectinase. Apart from fibre, monogastric animals are not capable of digesting phytates, tannins and anti-nutrients although the bacterial flora in the caecum and the large intestine to a small extent facilitates these processes. Phytase introduced into the diet of monogastric animals allowed using phytic phosphorus from plant-based feed. Enzymatic preparations containing phytases and phosphatases of microbiological origin give rise to phytin hydrolysis and release P in the upper sections of the gastrointestinal tract of animals.

The introduction of feed enzymes is safe since, similar to endogenous enzymes, they are broken down by proteolytic enzymes in the small intestine. Therefore, an overdose of enzymatic preparations is safe to animal health and does not leave any harmful decomposition products, so they can be used until the end of the fattening period. Enzymes act in the clearance of the gastrointestinal tract and do not disturb the functions of internal organs.

The use of enzymatic preparation in pig feed is the most justified in the nutrition of piglets due to insufficient development of their enzymatic system and instability of their intestinal microflora (De Lange et al., 2010). Low enzymatic activity in the gastrointestinal tract of young pigs causes poor digestion and conversion of feed ingredients that become a medium for the growth of pathogenic bacteria in the intestines and provoke diarrhoea. Thus, the underlying recommendation in the nutrition of piglets is using the highest quality feeds that are highly digestible and have a relatively low fibre content. Meanwhile, the results of numerous studies (Li et al., 2004, Osek and Milczarek, 2004; Flis and Sobotka, 2005; Vahjen et al., 2007; Hanczakowska et al., 2012; Chen et al., 2016) indicate that correctly targeted feed enzymes added to a pig diet can significantly reduce the production costs and allow using even poorly digested raw materials. The fundamental component of feed for each technological group of pigs is cereals (often barley) characterised by a high content of non-starch polysaccharides (NSP) (Li et al., 2004). The digestibility and conversion rate of feeds with high NSP content are improved by adding xylanase and beta-glucanase. Sterk et al. (2007) demonstrated that xylanase introduced into the diets of weaned piglets improved the digestibility of protein, fat, fibre and non-starch polysaccharides. Similarly, Hanczakowska et al. (2006) compared the production performance of weaned piglets receiving feed with added xylanase and beta-glucanase. The authors found that after administration of both enzymes the weight gain of piglets increased by 17% and 14% respectively for supplementation of glucanase and xylanase in relation to the control group. In turn, Milczarek et al. (2006) observed that beta-glucanase added to feed rations containing naked oats decreased the conversion of feed and nutrients by about 6% per 1 kg of weight gain in comparison to pigs fed identical feed rations but without the enzyme. The aforementioned results were confirmed by studies carried out by Vahjen et al. (2007) and Chen et al. (2016). Chen et al. (2016) showed that xylanase of bacterial or fungal origin added to feed for weaned piglets increases daily weight gains (by 3.25% and 8.22%) and decreases the count of Escherichia coli (by 12.98% and 11.68%), at the same time increasing the count of lactic acid bacteria (by 16.21% and 27.02%) in the ileum compared to the control group. Another enzyme often added to feed rations for piglets is protease which supports protein conversion (Tactacan et al., 2016; Min et al., 2019; Park et al., 2020). Tactacan et al. (2016) showed that the use of commercial protease in the diets of weaned piglets improves the digestibility of protein, which increases daily weight gain (491 g vs 460 g), and decreases ammonia emission. Furthermore, Park et al. (2020) found a reduced number of episodes of diarrhoea in piglets receiving feed with added protease. In turn, Min et al. (2019) observed that the supplementation of protease improves daily weight gain by ca. 44g and decreases feed conversion by ca. 0.018 kg. Phytase is another important enzyme boosting the availability of naturally non-assimilable phytic phosphorus from fodder forming a part of the feed ration for pigs (Grela and Kumek, 2002; Guggenbuhl et al., 2012). Grela and Kumek (2002) showed that introducing the microbiological phase into food rations for sows resulted in releasing minerals and nutrients, which contributed to improved productivity. In addition, the animals showed increased digestibility of nutrients (Ca and P) and their higher content in milk. Similarly, Guggenbuhl et al. (2007) demonstrated that phytase added to diets of fattening pigs considerably increased the digestibility of phosphorus and reduced its excretion with faeces. The digestibility of calcium also improved. The use of phytase can contribute to cutting down on feed production costs by reducing the number of calcium and phosphorus additives used in pig feed rations.

## ORGANIC ACIDS/PRESERVATIVES

Organic acids/preservatives are substances preventing feed from spoiling, inhibiting the growth of bacteria and moulds in feed during storage and having a beneficial effect on the function of the gastrointestinal system in animals (Hansen et al., 2007; Hanczakowska et al., 2011). Preservatives include short-chain organic acids: propionic, formic, lactic, sorbic, fumaric, citric and orthophosphoric as well as caprylic and capric acid. Organic acids reduce both the pH of feeds and the pH in the gastrointestinal system of pigs, which prevents the growth of pathogenic bacteria. In addition, they can penetrate through the cell wall and destroy pathogenic bacteria (Hansen et al., 2007; Hanczakowska et al., 2011; Long et al., 2018). The use of preservatives in feed is most significant in young animals that are the most susceptible to diseases. Hansen et al. (2007) proved that organic acids introduced to a feed ration improve weight gain, decrease feed conversion, have a beneficial stimulating effect on gastrointestinal microflora by preventing the growth of pathogens and reducing piglet mortality. Similarly, Lawlor et al. (2006) showed that 20g of fumaric acid added to 1 kg of feed had a positive effect on the production performance of animals, e.g. body weight and feed intake. In turn, Hanczakowska et al. (2011), comparing the effect of fumaric acid alone or of fumaric acid with caprylic or capric acid added to do diets of piglets, found higher weight gains and lower mortality rates for experimental piglets compared to the control group. In addition, the acids reduced the count of *Escherichia coli* in the small intestine of piglets; the most effective was fumaric acid which also decreased the count of *Clostridium* bacteria. Partanen et al. (2007) verified the beneficial effect of formic acid and two types of mixture of formic acid: I - with propionic acid and potassium sorbate, II - with propionic acid and sodium benzoate and formic acid in a diatomaceous earth carrier, used in feed rations for weaned piglets, weaners and fattening pigs on their production performance. The authors noted enhanced weight gain in weaned piglets, reduced intensity of diarrhoea and higher intake of feed among animals from all experimental groups during the whole fattening period, which was reflected in a higher slaughter weight of pigs compared to the control group. Gerritsen et al. (2010) found that a mixture of formic acid and essential oils as well as a mixture of formic acid with propionic, lactic, citric or sorbic acid added to piglet feed increased the digestibility of crude fibre in the feed. In addition, the mixture of formic acid with essential oils improved the digestibility of carbohydrates. In turn, Liu et al. (2014) added citric acid to the feed for sows and found an increase in the content of protein and immunoglobulins in the colostrum and in the milk. This boosted the health of piglets, reduced the intensity of diarrhoea and piglet deaths and enhanced their weight gain. Similarly, Balasubramanian et al. (2016a) and Devi et al. (2016) noted that acids added to feed for lactating sows both enhanced the conversion and digestibility of feed in sows and boosted the health of their piglets. Studies by Devi et al. (2016) showed that the supplementation of a mixture of protected organic acids (fumaric, citric, malic, capric and caprylic acid) to the feed for sows in the amount of 0.1% and 0.2% increased the count of *Lactobacillus* bacteria and decreased the count of *Escherichia coli* in the faeces of sows, reduced the emission of $NH_3$ and $H_2S$ and increased the concentration of immunoglobulin G in blood. Piglets whose mothers received organic acid supplements were also characterised by higher levels of immunoglobulin G and a higher white blood cell count right after labour and throughout the rearing period. In turn, Lan and Kim (2018) demonstrated that a mixture of organic acids and medium-chain fatty acids included in sow feed enhanced daily weight gain in suckling pigs and increased the count of beneficial probiotic *Lactobacillus* bacteria, at the same time decreasing the count of

*Escherichia coli* in the faeces of sows and piglets on the weaning day.

## PROBIOTICS

Probiotics are feed additives containing correctly selected bacteria naturally occurring in the intestines which, when taken in with feed, settle in the alimentary tract. Probiotics for pigs are produced with the use of lactic acid bacteria, i.e.: *Lactobacillus casei*, *Lactobacillus plantarum*, *Lactobacillus lactis*, *Lactobacillus acidophilus*, *Bifidobacterium bifidum*, *Pediococcus acidilacti*, *Enterococcus faecium*, and *Bacillus subtilis*. Probiotics have a multi-directional effect and are especially efficient when the correct homeostasis of microflora in the gastrointestinal tract is disturbed (diarrhoea, long-term intake of therapeutic antibiotics). The main effects of probiotic microorganisms include: a change of pH in specific sections of the gastrointestinal tract due to organic acids (lactic, acetic, propionic acid) being produced by probiotic organisms. Acidity in the gastrointestinal tract inhibits the growth of most pathogenic and relatively pathogenic bacteria that are present there, production of bacteriostatic and bactericidal substances such as: hydrogen peroxide, lysosymes, bacteriocin, lactolin, acidolin, acidophilin, bulgaricin, reuterin; reduction in the level of toxic amines and ammonia produced by pathogenic bacteria in the gastrointestinal tract; stimulating effect on the immune system leading to an increase in the level of interferon and immunoglobulins in blood serum, which boosts the phagocytic activity of lymphocytes (Grela and Semeniuk 2006).

Probiotic preparations can be also supplemented with yeasts, such as *Saccharomyces cerevisiae*, *Saccharomyces boulardii*, as well as vitamins and immunoglobulins. Yeasts have a positive effect on the health and productivity of both ruminants and monogastric animals but are not capable of settling in their gastrointestinal tract in contrast to lactic acid bacteria. The yeasts *Saccharomyces cerevisiae* have peculiar properties. Their cell walls are built, among other components, from mannan-oligosaccharides. The activity of yeasts is also characterised by a wide spectrum of effects: they adjoin intestinal epithelium and prevent nesting and reproduction of pathogenic bacteria, decrease the pH, stimulate lymphocytes and boost the activity of IgG and IgM immunoglobulins as well as create barriers against the invasion of pathogenic microorganisms, absorb antigens produced by pathogenic bacteria, activate digestive enzymes and ensure water balance in the body.

Zeyner and Boldt (2006) demonstrated that a probiotic containing strains of *Enterococcus faecium* added to piglet diet during the first 3 days after birth decreased the frequency of diarrhoea. Similarly, Guerra et al. (2007) and Bernardez et al. (2008) noted the limited intensity of diarrhoea in piglets at the weaning age after the introduction of probiotic bacteria (P*ediococcus acidilacti*, *Lactococcus lactis*, *Lactobacillus casei* and E*nterococcus faecium*) into feed rations, which contributed to enhanced daily weight gain. The authors observed that the probiotic added to the feed had a similar effectiveness to that of an antibiotic. The positive effect of lactic acid bacteria on the growth, health and development of piglets at the weaning age is confirmed by Bedford et al. (2014) who demonstrated that epidermal growth factor-expressing *Lactococcus lactis* fermentation product administered to piglets increased their daily weight gain by 54.3 g and decreased feed conversion rate by 0.087 kg. Numerous studies (Taras et al., 2006; Zhang et al., 2020; Lin and Yu, 2020) indicate that probiotic preparations fed to lactating sows also improve the health of piglets. Link et al. (2016) verified the positive effect of the probiotic containing the spores of *Bacillus licheniformis* and *Bacillus subtilis* added to the feed for both piglets and sows. The authors noted increased intake of feed in sows, which contributed to reducing weight loss on the 14$^{th}$ day after labour. In addition, their blood and milk parameters improved, which had a positive effect on the litter. The positive effect was manifested in decreased mortality of pigs before the weaning age, improved health to the extent of reducing the frequency of diarrhoea, and enhanced weight gain during the weaning process. Similarly, Taras et al. (2006) found that a probiotic containing strains of *Enterococcus faecium* added to feed rations for lactating sows decreased piglet mortality by 6 pp (percentage points) in the experimental group as compared to the control group. In addition, the authors noted that such a probiotic included in the feed ration for piglets at the weaning age decreased the incidence of diarrhoea by 17 pp. Lan and Kim (2020) confirmed the positive effect of *E. faecium* added to feed for sows, since they noted increased digestibility of feed in the gastrointestinal system and decreased mortality rate of piglets before the weaning age. In addition, piglets from the experimental group were characterised by higher daily weight gain and better health due to a reduction in the number of diarrhoea episodes in the first week after weaning. Similarly, Zhang et al. (2020) noted a beneficial effect of 4.0 x $10^8$ CFU/kg *B. subtilis* PB6 added to feed administered to sows at late stages of pregnancy and during lactation on reducing the time between labours, increasing the weight gain of suckling pigs and improving intestinal health. Jørgensen et al. (2016) reports that a probiotic containing strains of *Bacillus* spp. administered to piglets after the weaning age and then to fattening pigs until slaughtered resulted in increased daily weight gains. However, the authors found that the additive was most effective in young pigs between day 42 and day 120 of life. A positive effect of probiotic preparations containing strains of *Bacillus* spp. added to the feed on the weight gain of fattening pigs was confirmed by Meng et al. (2010), Balasubramanian et al. (2016) and van der Peet-Schwering et al. 2020. Balasubramanian et al. (2016), aside from the improved production performance of pigs, observed a beneficial effect of the probiotic on the slaughter value of pigs. Dietary supplementation with *Bacillus* spp. probiotic resulted in a significant linear effect on sensory evaluation of meat colour and drip loss at day 3.

## PREBIOTICS

Prebiotics are a medium stimulating growth and development of the beneficial gastrointestinal microflora in pigs, and hence displace potentially harmful bacteria. Prebiotics are subject to selective and fast bacterial fermentation in further sections of the gastrointestinal tract, where they stimulate the growth of lactic acid bacteria, in particular *Bifidobacterium*, and have a bifidogenic effect involving selective fermentation of fructans by bifidobacteria synthesizing ß-fructosidase. Prebiotics supplied to animals and used by bacteria induce changes in the count and type of bacteria in the intestines. They also reduce the occurrence of pathogenic bacteria such as *Escherichia coli*, *Salmonella*, *Shigella*, *Campylobacter jejuni* and *Clostridium perfringens*, as well as toxins produced by such bacteria, which increase the resistance of animals. Popular prebiotics are: inulin, lactose, lactulose, mannanoligosaccharides (MOS), agarooligosaccharides (AOS), fructooligosaccharides (FOS), ß-galactooligosaccharides (GOS) and other, such as for example plant extracts from *Yucca schidigera* (Grela et al., 2006). Prebiotics prevent adhesion of pathogenic bacteria (*Salmonella spp.*, E. coli spp.) to the mucosa of the gastrointestinal tract, and occupying space on the cell membrane of the intestines prevent bacteria from attaching to intestinal walls, which in consequence leads to their excretion together with undigested food and reduces the incidence and duration of diarrhoea in pigs.

Gyawali et al. (2015) claim that these substances stimulate the growth of beneficial microorganisms in animals and, fed to lactating sows, contribute to production of milk enriched with probiotic microorganisms. Studies carried out by (Awad et al., 2013; Chen et al., 2020; Wang et al., 2020) revealed that inulin-containing prebiotic added to the feed increased the count of *Lactobacillus* and *Bifidobacterium* strains in the gastrointestinal tract, and improved the absorption of glucose in the blood of weaned piglets. Similar effects were noted for piglets when the pregnant and lactating sows received inulin (Paßlack et al., 2015; McCormack et al., 2019; Li et al., 2020). Many studies (Grela et al., 2006; Castillo et al., 2008; Agazzi et al., 2020; Zhou et al., 2020) focused on the effect of mannooligosaccharides (MOS) as an additive to feed for piglets at weaning age. The results of studies (Grela et al., 2006; Castillo et al., 2008) indicate that even a small supplementation of MOS (0.1-0.2%) of the feed ration for piglets reduces the incidence of diarrhoea and improves stool structure. In turn, Czech et al. (2010) demonstrated that 8 g MOS/day per sow supplemented 4 weeks before and 4 weeks after labour increased the content of immunoglobulin G (IgG) in the colostrum, which improved the survival rate and health and enhanced daily weight gain of piglets. Prebiotics containing fructooligosaccharides (FOS) also have a beneficial effect on the development of the gastrointestinal system of piglets. For example, they reduce the incidence of post-weaning diarrhoea, and contribute to extension of intestinal villi thus increasing the feed conversion rate (Liu et al., 2017; Ayuso et al., 2020).

## HERBS AND HERBAL EXTRACTS (PHYTOBIOTICS)

Herbs and herbal extracts (phytobiotics) are used for the treatment of diseases both in humans and in animals. Herbs and essential oils are used in pig nutrition due to their antibacterial, anti-inflammatory, antioxidant and anti-parasite properties (Grela and Semeniuk, 2006; Grela and Klebaniuk, 2007; Liu et al., 2017; Lei et al., 2018; Zhao et al., 2019). The characteristics of selected herbs used in pig nutrition are presented in Table 1.

Studies (Rekiel et al., 2011; Hanczakowska and Świątkiewicz, 2012; Costa et al., 2013; Zhai et al., 2018; Pastorelli et al., 2020) on the applications of herbs in pig nutrition showed many positive results (improved flavour of feed, enhanced appetite, regulated digestive and metabolic processes) in animals from each production group. An addition of correctly selected mix of herbs for sows improves the intake of feed, and its supplementation in the periparturient period can have a beneficial effect on the composition and quality of milk as well as on the health and survival of new born piglets (Costa et al., 2013; Liu et al. 2017; Oh et al., 2020). Grela and Klebaniuk (2007) found that powdered garlic supplemented to piglets in the feed enhanced weight gain, and reduced the number of piglet deaths and blood cholesterol level. In turn, Yan and Kim (2013) demonstrated that fermented garlic powder in the amount of 1-2 g/kg feed increased the digestibility of the feed, raised the count of lymphocytes in blood and reduced the count of pathogenic *Escherichia coli* bacteria in faeces. Jang et al. (2010) noted that an herbal mix (artemisia, acanthopanx and garlic) used in the diet of lactating sows improved their condition in the period of lactation and enhanced piglet weight gain. Allan and Bilkei (2005) showed that oregano (in the form of dried leaves mix and cold pressed seed oil) administered to sows prior to labour improved the intake of feed and the reproductive performance in the experimental group, increased the fertility of subsequent litters and the rate of survival of new born piglets. Rekiel et al. (2011) demonstrated that the Payapro herbal extract administered in the amount of 15g/sow/day from the second day prior to labour until the 12$^{th}$ day after labour improved the composition of sow milk (increased content of protein, fat and lactose), and significantly lowered the share (50.7%) of somatic cells. Similar production and reproductive performance of sows as well as weight gain and health of their offspring after supplementation of the herbal additive (oregano, cinnamon, Mexican pepper) was noted by Matysiak et al. (2012). Liu et al. (2017) found that a mix of herbal extracts (*Scutellaria baicalensis* and *Lonicera japonica*) used as an addition to the diets of sows under thermal stress improves the intake and digestibility of feed and has a beneficial effect on the weight gain and weaning weight of piglets. Herbal mixes are widely used as additives to feed for piglets and weaners (Khan et al., 2009; Hanczakowska and Świątkiewicz, 2012; Lei et al., 2018; Zhao et al., 2019; Wang et al., 2020). Hanczakowska and Świątkiewicz (2012) demonstrated that an extract from sage, lemon balm, nettle and echinacea added in the amount of 500 mg/kg feed for piglets contributed to extending their intestinal villi, and thus improved the digestibility and conversion of the feed ration. In turn, Khan et al. (2009) noted that feed containing an extract from *Acacia nilotica*, *Syzygium aromaticum* and *Cinnamomum zeylanicum* reduced post-weaning diarrhoea (induced by Escherichia coli) in piglets. Hossain et al. (2015) found that an extract from fenugreek seeds also contributed to decreasing the count of *Escherichia coli* in the faeces of sows and piglets and reduced ammonia emission. The authors also demonstrated that sows receiving feed enriched with the extract had higher levels of immunoglobulin G and erythrocytes in blood. Lipiński et al. (2014) proved that the use of a preparation containing extracts of herbs

**Table 1.** Properties of herbs used as pig feed additive

| Plant | Active ingredients | Effect |
|---|---|---|
| Baikal skullcap (*Scutellaria baicalensis* L.) | *flavones (baicalin, baicalein, wogonoside, wogonin and oroxylin A)* | anti-inflammatory, bacteriostatic, antioxidant |
| Caraway (*Carum carvi* L.) | essential oils, flavonoids, tannins, organic acids | stimulating digestion, diastolic, calming, cholagogic |
| Chamomile (*Matricaria chamomilla* L.) | essential oils, mucilages, flavonoids, glycosides | anti-inflammatory, diastolic, cholagogic, calming |
| Clove (*Syzygium aromaticum* L.) | essential oils, eugenol | antioxidant, bacteriostatic |
| Coach grass (*Agropyron repens* L.) | essential oils, saponins, mucilages, organic acids | diuretic, cholagogic, anti-inflammatory, bacteriostatic |
| Common yarrow (*Achillea millefolium* L.) | essential oils, mucilages, flavonoids, glycosides (achilleine), tannins | anti-inflammatory, haemostatic, diastolic, detoxifying, bacteriostatic |
| Dandelion (*Taraxacum officinale* L.) | terpenes, phytosterols, bitters (taraxacine), biogenic stimulators, flavonoids | stimulating appetite, diastolic, cholagogic, anti-inflammatory, bacteriostatic |
| Garlic (*Allium sativum* L.) | essential oils, flavonoids, saponins, phytosterols, mucilages | bacteriostatic, hypotensory, cholagogic, stimulating digestion |
| Ginger (*Zingiber officinale* L.) | α-Zingiberene, α-Farnesene, α-Pinene, Camphene, linalool, β-Pinene, geraniol, citral, β-Phellandrene, limonene, cineol | anti-inflammatory, bacteriostatic, antioxidant |
| Knotgrass (*Polygonum aviculare* L.) | flavonoids, tannins, organic acids | anti-diarrhoeal, diuretic, detoxifying, boosting metabolism |
| Lemon balm (*Melissa officinalis* L.) | leaves, herb, essential oils, flavonoids, mucilages, terpenes | calming, stimulating digestion, bacteriostatic |
| Marjoram (*Origanum majerana* L.) | essential oils, tannins, bitterness compounds | diastolic, anti-inflammatory |
| Narrowleaf plantain (*Plantago lanceolata*) Broadleaf plantain (*Plantago maior* L.) | tannins, flavonoids, glycosides (aucubin), organic acids | anti-inflammatory, diuretic, detoxifying, bacteriostatic |
| Nettle (*Urtica dioica*) | flavonoids, phytosterols, carotenoids, organic acids | haemostatic, detoxifying, bacteriostatic, anti-diarrhoeal |
| Oregano (*Origanum vulgare* L.) | essential oils (thymol, carvacrol), flavonoids | bacteriostatic, anti-diarrhoeal, diuretic, |
| Pepper mint (*Mentha piperita* L.) | essential oils, flavonoids, tannins, organic acids | stimulating digestion, cholagogic, diastolic, bacteriostatic |
| Purple coneflower (*Echinacea purpurea* L.) | caftaric acid, chicory acid | antiseptic, antibacterial, anti-inflammatory, |
| Sage (*Salvia officinalis* L.) | essential oils, tannins, terpenes, flavonoids | anti-inflammatory, antispasmodic, antibacterial |
| Silverweed (*Pontentilla anserine* L.) | flavonoids, tannins, mucilages, phytosterols, organic acids | anti-inflammatory, anti-diarrhoeal, diastolic, cholagogic |
| St. John's wort (*Hypericum perforatum* L.) | flavonoids, tannins, essential oils | calming, cholagogic, antispasmodic, bacteriostatic |
| True cinnamon tree (*Cinnamomum verum* L.) | cinnamaldehyde, eugenol, cinnamyl acetate, linalool | antiseptic, antibacterial, anti-inflammatory, stimulating |
| Thyme (*Thymus vulgaris* L.) | essential oils | bacteriostatic, antioxidant, antifungal |

(*Adrographis paniculata*, *Phyllanthus emblica*, *Curcuma longa*, *Zingiber officinale* and *Allium sativum*) in the feed rations for sows increases the intake of feed (5.84 kg vs 5.46 kg) but also enhances their milk yield (7.58 kg vs 6.71 kg). In addition, the combination of feed with a herbal preparation had a positive effect on piglets as they grew faster and had a higher body weight on the weaning day.

## CONCLUSIONS

To sum up, the paper describes a wide selection and multidirectional effects of feed additives introduced to the diets of sows and their offspring. The documented studies lead to a conclusion that feed additives have a positive effect on the health status and productivity of animals but their use requires thorough knowledge and constant management of their effects. It should also be remembered that the efficiency of feed additives used in the nutrition of sows and their offspring is reflected in the productivity of growing pigs and, as a result, in the economic performance of a pig breeding farm.

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