Wiadomości Zootechniczne, R. LVI (2018), 3: 167–174

Sources of Energy for Newborn Piglets and the Possibility of Regulating Them

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The birth process of new-born piglets means a sudden change - from a comfortable intrauterine environment to a dangerous independent life (Theil, 2017). According to Le Dividich (2006), pre-weaning mortality of piglets (28th day of life) reaches 17-20% in pig producing countries (one in 5-6 piglets does not survive from the beginning of birth until weaning). According to Alonso-Spilsbury (2007), it is 12-25%, and Mainau et al. (2015) estimate that it reaches even 35%. As the number of litter increases, piglets mortality increases as well (Edwards, 2002, Le Dividich, 2006). The highest occurs in the first 2-3 days of life (Tuchscherer et al., 2000, Le Dividich, 2006, Theil, 2017) and constitutes 50-70% of all the mortality cases (Le Dividich, 2006). Many authors quote bruising as the main cause of mortality (Damm et al., 2005; Mainau et al., 2015) although - as Le Dividich (2006) points out - the causes of such high mortality are not fully understood and the bruising is probably the last link in the chain of events leading to the deaths of piglets. The survival of piglets is a result of complex interactions between the sow, the piglet and the environment (Edwards, 2002). Many authors emphasise that high mortality is primarily a result of low energy reserves of new-born piglets (Pettigrew, 1981, Bishop et al., 1985, Andersen et al., 2009, Declerck et al., 2016). In order to reduce mortality, it is therefore necessary to meet the energy needs of the new-born piglets.

The energy demand for piglets and the sources of its acquisition

Piglets are born with very low energy reserves. At first, the new-born ones can draw energy from three sources: glycogen, colostrum and transitional milk (Theil et al., 2014). At the same time, they have very high demand for energy related to, among others, thermoregulatory needs, increased physical activity and sucking (Le Dividich et al., 1994, Marion and Le Dividich, 1999, Herpin et al., 2002). If one of these energy sources is not ensured, piglets die as a result of hunger or weakness resulting in bruising (they are not able to react to the change of position by the sow) (Theil et al., 2014). It is estimated that the total energy reserves of piglets are only about 430 KJ / kg, while their demand in the first day of life is about 900-1000 KJ / kg of body weight (Mellor and Cockburn, 1986). According to Le Dividich et al. (1994) and Marion and Le Dividich (1999), in the conditions of minimal energy use related to thermoregulation, nutrition and physical activity, the energy demand is approximately 275 KJ / kg of body weight in piglets. In practice, however, the energy demand for piglets is higher, which results from high physical activity associated with sucking and heat stress (Le Dividich, 2006).

Glycogen, the first source of energy for piglets, is stored in their livers and muscles (Elliot and Lodge, 1977, Père, 2003; Pejsak, 2006), and its accumulation begins one month before the birth (Père, 2003). Glycogen reserves, however, are very low - 30-38 g / kg of body weight (Elliot and Lodge, 1977) and after birth are subject to a very rapid reduction (Elliot and Lodge, 1977; Le Dividich et al., 2005), especially if piglets need to metabolise glycogen to maintain the regular body temperature (around 40°C) (Noblet and Le Dividich, 1981, Herpin et al., 2002, Le Dividich et al., 2005). According to Le Dividich (2006), the energy necessary for thermoregulation of new-born sucklings is 48 KJ / $kg^{0,75}$ of body weight/°C and is therefore 2.6 times higher than in separated piglets. In new-born piglets, glycogen concentration is higher in the liver than in the muscles as confirmed by studies conducted by Theil et al. (2011). These studies indicate that the glycogen concentration in the liver was about 9.6% of the liver mass and was on average higher by about 12.5% as compared to the glycogen concentration in the semi-membranous muscle (*m. semimembranosus*) and about 24% as compared to the diaphragm (*m. diaphragma*). The muscles store as much as 89% of all glycogen reserves (Elliot and Lodge, 1977), which is due to their higher total weight as compared to the liver (Theil et al., 2011). Glycogen contained in muscles is the main source of energy used during movement (English and Morrison, 1984). As already pointed out earlier, glycogen concentration is reduced very quickly. The research by Boyd et al. (1978) shows that after 6 hours following the delivery, the concentration of glycogen in the liver of piglets decreased by 51%, and after 24 hours - by 86%. Research results by Theil et al. (2011) additionally indicate a faster reduction of glycogen in the liver than in the muscles. After 32.5 hours postpartum glycogen concentration in the liver decreased by 80%, in the semi-membranous muscle by 64% and in the diaphragm by 46%.

Low energy reserves of piglets in the form of liver and muscle glycogen and their quick use (high energy demand of animals), underline the importance of early delivery of another source of energy to new-born piglets and the need to try to increase its reserves.

Possibilities of increasing the reserves of muscle and liver glycogen of piglets

The low level of energy reserves in new-born piglets often prevents proper development and functioning. Weaker individuals are more exposed to hypothermia, hypoglycaemia and do not have enough strength for hierarchical fights for a place at the milk bar during feeding (Pejsak, 2006). Increasing the energy reserves of new-born piglets would reduce the pre-weaning mortality rate.

The attempt to increase piglets' energy reserves in the form of glycogen has been undertaken by numerous authors. The research by Gabler et al. (2007) shows that enriching the diet of pregnant and lactating sows with polyunsaturated fatty acids (PUFA) positively affects the concentration of glycogen in the muscles of weaned piglets and also increases the absorption of glucose in the jejunum (*intestinum jejunum*) of piglets. The authors indicate that polyunsaturated fatty acids from the omega-3 family in the sow diet can contribute to alleviating the weaning stress of piglets and affect their growth and health. According to Mirowski (2017), a higher concentration of glycogen in the liver and muscles of weaned piglets may result from improved glucose absorption by animals, which results in faster adaptation to dietary changes and better use of nutrients. Jean and Chiang (1999) also noted the effect of feeding on the amount of glycogen reserves in piglets. In the offspring of sows fed with medium-chain triglycerides and coconut oil, a higher content of muscle glycogen was recorded as compared to the offspring of sows fed a diet enriched with soybean oil. The authors of the study indicate that this may be the reason for easy penetration of medium-chain triglycerides contained in coconut oil. The ketone bodies resulting from the conversion of fat into energy after penetration through the placenta are likely to stimulate the accumulation of glucose reserves (Seccombe et al., 1977, Shambaugh, 1985). In turn, Bishop et al. (1985) studied the effect of the addition of soybean oil in the sow diet during late pregnancy to the glycogen content in the liver of new-born piglets. These studies show that soybean oil does not affect the content of liver glycogen. Newcomb et al. (1991), using three different energy sources during its study: starch, medium-chain triglycerides and soybean oil, did not record changes in glycogen content in piglets, either. In turn, Boyd et al. (1978) investigated the influence of energy sources - carbohydrates or fats in the dietary dose of sows before delivery and during lactation on the glycogen content in the livers of new-born piglets. The obtained results indicate a higher content of glycogen in the livers of piglets from sows whose main source of energy were fats (188 mg / g of liver moist weight) in comparison with piglets born by sows whose main source of energy in the ration were carbohydrates (175 mg / g weight of moist liver). However, these differences have not been confirmed statistically. Theil et al. (2011) attempted to increase the glycogen reserves of new-born piglets by introducing diets with low fibre and high-fibre content in the sows' diets. In the period from mating up to 108 days of pregnancy, dietary doses with low fibre (17% - 1 group) or high fibre (3 groups - 32-42%) were used. The diets of sows over 108 days of pregnancy differed in the type of fat used - animal fat, fish oil, sunflower oil, coconut oil, caprylic acid + fish oil. The obtained test results did not show statistically significant differences in the amount of glycogen in piglets. The average glycogen content in new-born piglets - regardless of the diet used in pregnant sows (low fibre or high fibre content) and in sows during lactation (the type of fat used) - was about 2.1 g in the liver and about 39.5 g in the muscles.

Undertaking attempts to increase the reserves of liver and muscle glycogen of new-born piglets is very important for their proper development. Studies carried out so far indicate that thanks to the appropriate modification of the composition of the sows' feed the piglets are born with higher energy reserves.

Colostrum and milk in the diet of piglets

The selection of animals carried out in recent years has caused, on the one hand, a significant improvement in the piglet growth rate, the reduction of their fat tissue and the increase in litter size, and, on the other hand, increased the mortality of piglets (Canario, 2006) and their greater variation in the litter (Le Dividich et al. , 1991, Herpin et al., 1993, De Vos et al., 2014). As Foxcroft et al. indicate, (2006), the congestion of piglets inside the uterus, especially after the 35th day of pregnancy, is the main factor limiting live births and the growth and weight of foetuses. The mortality rate of piglets with low birth weight increases from 7% in the litter size of 11 piglets to 23% in litters over 11 piglets (Martineau and Badouard, 2009). Theil et al. (2011) and Mirowski (2017) emphasise that the glycogen reserves in new-born piglets depends mainly on their body weight. The research by Pastorelli et al. (2009) shows that the glycogen content in the muscles of the heaviest and lightest piglets in the litter 20-36 h after delivery is - about 1260 mg / kg of body weight (immediately after delivery - approx. 1410 mg / kg). Furthermore, the results indicate a constant liver mass - about 49.2 g, regardless of the weight of the piglets.

The second (in addition to glycogen) source of energy which the animals can use is the adipose tissue. Piglets, however, are born with its very low content, less than 2% (Berge and Indörg, 1954; Mc Cance and Widdowson, 1959; Brooks et al., 1964; Wood and Groves, 1965; Brooks and Davis, 1969; Seerley and Poole; , 1974, Newcomb et al., 1991; Theil et al., 2014), corresponding to 10-20 g fat / kg of the body weight of piglets (Pejsak, 2006). The majority of adipose tissue occurs in the form of structural fats in cell membranes and thus cannot be oxidised (Pastorelli et al., 2009, Theil et al., 2014).

Due to such low energy reserves at birth, the mortality of piglets depends mainly on the consumption of colostrum (Alston-Mills et al., 2000, Declerck et al., 2016). In comparison with milk, colostrum is characterised by a higher content of dry matter, protein and lactose while milk - fat content (Koska and Eckert, 2016). Both of them can be influenced, among others, by modifying the contents of the sows' diets, as evidenced by numerous studies. Jackson et al. (1995), using the addition of maize oil in the diet of pregnant sows found a higher fat content in milk whereas Loisel et al. observed (2013) a higher fat content in colostrum in sows fed during the period from late pregnancy (106th day) to the application of a mixture with a higher content of dietary fibre. Mazur and Stasiak (2006) obtained a higher protein content in milk using a mixture of 30 g fat / kg of feed in sows compared to the milk of sows receiving 20 or 40 g of fat while Liu et al. (2014) recorded higher protein content in the milk of sows fed with a mixture with the addition of citric acid (15 g / kg of feed). According to Hurley (2015), the gross energy of the colostrum during delivery is approximately 6.7 KJ / g and raises to the 3rd day of lactation and, then, gradually decreases. As indicated by the above author, the high energy level of colostrum is associated with a high concentration of immunoglobulins in it, which are, however, more resistant to digestion as compared to other milk proteins and the amount of amino acids absorbed by piglets is also lower as compared to other whey proteins (Yvon et al. 1993, Danielsen et al., 2011). The transient gross energy increase observed on days 2 and 3 of lactation is probably related to the peak fat content that occurs during this lactation phase (Hurley, 2015).

The basic difference between colostrum and mature milk is, apart from the composition, also the period during which the secretions are produced (Theil et al., 2014). The secretion of colostrum begins several hours before delivery while milk is produced after delivery (Klobasa et al., 1987). Some authors believe that the amount of colostrum produced is constant regardless of the number of piglets in the litter (Foisnet et al., 2010) and animal breeds (Declerck et al., 2015). Theil (2017), however, points to a correlation between the performance of colostrum and the number of live piglets born, which could explain the production of colostrum also after the birth. Quesnel et al. (2009) and Loisel et al. (2013) in their research attempted to increase the amount of colostrum produced by sows. This production is regulated hormonally, mainly by progesterone and prolactin (Quesnel et al., 2012). Quesnel et al. (2009) as a result of feeding sows with the mixtures with a higher fibre content increased the prolactin concentration before the birth but, nevertheless, they did not notice any difference in the amount of colostrum. In turn, Loisel et al. (2013) investigated the effect of dietary fibre administered to sows during late pregnancy (from the 106th day of pregnancy to the birth) on the hormonal changes that could stimulate the growth of colostrum production. The experimental animals were fed with a compound feed containing 13.3% or 23.4% of the total dietary fibre, however, the applied dietary changes did not affect the concentration of hormones in the sows or the amount of colostrum.

The first intake of colostrum by offspring probably takes place 20 minutes after delivery (Devillers et al., 2004). The speed of its collection by piglets is initially very high (5-7% of the birth weight in the first 2 h of life) and, then, gradually decreases (Fraser and Rushen, 1992). It is estimated that small amounts of colostrum are available in the mammary gland up to 16 h after the birth of the first piglet (Theil et al., 2014).

The amount of colostrum required to deliver carbohydrates and lipids to meet the needs of newborn animals is high (Mellor and Stafford, 2004). According to Hulsen and Scheepens (2014), a new piglet during the first 12 hours of life consumes, on average, 15 portions of colostrum of 15 ml each (i.e. 225 ml). Le Dividich et al. (2005) and Devillers (2004) report that piglets should take about 160 gram of colostrum per kilogram of body weight to survive. Hernández-Castellano et al. (2018) estimated that in order to reduce the risk of mortality, provide passive immunity and gain weight, the piglet should take a minimum of 200 g of colostrum within the first 24 hours after the birth. According to Quesnel et al. (2012), if piglets consume over 200 g of colostrum, their mortality is below 10%, and if - 100-200 g colostrum - 34%. The consumption of less than 100 g of colostrum results in mortality at the level of 63%. Hernández-Castellano et al. (2018) also indicate that the consumption of 250 g of colostrum could improve the healthiness of piglets both before and after weaning but they also point out that as many as 1/3 of the sows do not produce enough colostrum to meet the needs of piglets. Insufficient amount of colostrum in the diet of sucklings leads to energy deficits and poorer viability of piglets (Pejsak, 2006, Devillers et al., 2011, Theil et al., 2014). As a consequence, the animals do not have enough strength for hierarchical fights for a place at the milk bar during feeding. Moreover, as a result of a shortage of food in the weakest individuals, hypoglycaemia, hypothermia, coma and even death may occur (Pejsak, 2006).

Both the production of colostrum by sows and its consumption by piglets is limited and highly variable (Le Dividich et al., 2005, Farmer and Quesnel, 2009, Devillers et al., 2011, Declerck et al., 2017). Devillers et al. (2011) indicate that the consumption of colostrum by piglets depends on both the amount produced by the sow and the piglets' ability to retrieve it. The research by Declerck et al. (2017) shows that the amount of colostrum taken by piglets was dependent on the breed of animals (Topigs Norsvin, Hypor, Danbred) and amounted to about 371 g. In addition, the consumption of colostrum by piglets was lower when sows received oxytocin during labour and decreased with the increasing number of litter. There was also a positive correlation between the amount of consumed colostrum and the weight of piglets. The authors suggest that an effective way to counteract the lower intake of colostrum by lighter piglets in a litter is to shorten the period from birth to its first collection. The research by Loisel et al. (2013) shows that the diet of sows during late pregnancy may affect the amount of colostrum taken by piglets. The consumption of colostrum by piglets of low birth weight (<900 g) was higher in sows fed dietary sows with higher fibre content (23.4% or 13.3%), in this group of piglets also lower mortality was noted. Similar results are shown by Quesnel et al. (2009). From these studies, it appears that piglets born by sows fed during the pregnancy with the mixtures of higher fibre content grew faster than those whose mothers were fed with the mixtures of lower fibre content. As the reason for this phenomenon, the authors pointed to the negative correlation between the amount of colostrum consumed by piglets and its cunninine content, more of which were recorded in the colostrum of sows fed by mixtures with a higher fibre content. In turn, Declerck et al. (2016) in their research attempted to increase the amount of colostrum taken by piglets by giving them a commercial energy supplement (Vigorol). There were no differences in the amount of collected colostrum, however, in the group of animals receiving an additional energy supplement, lower pre-weaning mortality was observed. According to the authors, the supplement provided piglets with additional energy and, thus, contributed to the saving of endogenous energy reserves.

Summary

The mobilisation of glycogen from the liver and muscles is essential for the survival of new-born piglets. Piglets are born with low energy reserves while their energy demand is high. Insufficient energy from glycogen or colostrum is probably the main cause of deaths of piglets before weaning. Increasing energy levels in new-born piglets could help reduce the pre-weaning mortality.

The increase in glycogen resources in the liver and piglets' muscles as well as the amount of colostrum can be influenced by the composition of the feeding dose of pregnant and / or lactating sows. Higher glycogen reserves of new-born piglets are recorded, for example, by enriching the diet of sows with medium-chain triglycerides. In turn, the higher content of dietary fibre in the sows' diet affects the higher intake of colostrum by piglets. And finally, the amount of colostrum consumed by piglets is influenced by the size of the litter, which negatively correlates with the amount of colostrum consumed by suckling pigs.

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SOURCES OF ENERGY FOR NEWBORN PIGLETS AND THE POSSIBILITY OF REGULATING THEM

Summary

The mobilisation of glycogen from the liver and muscles is essential for the survival of new-born piglets. Piglets are born with low energy reserves, while their energy demand is high. Insufficient amount of energy from glycogen or colostrum is probably the main cause of piglet deaths before weaning. Increasing energy levels in new-born piglets may contribute to reducing piglet mortality.

The increase in glycogen resources in the piglet's liver and muscles and the amount of colostrum intake can be influenced by modifications of the composition of the feed ration for the pregnant and/or farrowing sows. Higher glycogen reserve of new-born piglets is recorded, for example by enriching the diet of sows with medium-chain triglycerides; in turn, higher content of dietary fibre in the sows' diet affects the higher intake of colostrum by piglets. In addition, the amount of colostrum intake in piglets is influenced by the litter sizes, which negatively correlates with the amount of colostrum intake in suckling piglets.

Key words: glycogen, colostrum, sow nutrition, piglets

Photo 1. Suckling piglet in the first day of life (photo B. Jarocka)