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Gesellschaft für Versuchstierkunde
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Specialist Information

from the Committee for Nutrition of Laboratory Animals

Feeding concepts and methods in laboratory animal husbandry and animal experiments

- MINIPIG -

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Contents

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Introduction

Miniature pigs have been bred especially for research purposes since the end of the 1940s. Naturally occurring minipig breeds, such as the Minnesota minipig and the Vietnamese pot-bellied pig form the genetic background. Today, the Yucatan minipig and the Göttingen minipig are widely distributed.

The breeding of the latter was established in Friedland near Göttingen, Germany, between 1960 and 1965 as a crossbreed between Minnesota minipigs and Vietnamese pot-bellied pigs. It exists in a “colourful” (spotted, multicoloured) line and a white line, which arose through crossing the German Landrace breed (Glodek & Oldigs1981). The pigs were continuously selected for very small size and low body weight. The (hygienic) sanitation of the population carried out after 1969 had a strong impact on the body weight development, i.e. the sanitized pigs were just as heavy as those in the F0 generation at the start of breeding program. The selection had to be started again from scratch (Glodek & Wörner 1982).

Today, an adult, fully grown Göttingen minipig has a body weight of 35-45 kg. Minipigs in a similar weight class (35-55 kg) are, for example, the Yucatan micropig, the Sinclair and the Aachen minipig and also the Munich minipig. Other breeds, such as the Yucatan or the Hanford minipig, have body weights higher than 70-95 kg. Depending on the size of the pigs, the birth weights vary between about 0.4 and 0.6 kg in the case of the lighter breeds and between 0.6 and 1.0 kg in the case of the heavier breeds and weight development shows a more or less steep growth curve (Carfil Quality homepage; Ellegaard Growth Data 2011-2014; Musial et al. 1998; Bollen et al. 2000; Rozkot et al. 2015; Pawlowsky et al. 2017).

The minipig is important as a laboratory animal because its anatomical and physiological similarities to humans make it an interesting non-rodent animal model. Compared with other large animal species, it also shows a good reproductive performance. Moreover, cats and dogs have partially been replaced by minipigs since the use of pigs and minipigs in research is better accepted by the general public (less emotional reservation).

Minipigs are used in various research fields, including cardiovascular studies, dermatological and oncological research (e.g., Sinclair minipig as melanoma model), toxicological tests, diabetes research and also orthopaedic, dental and surgical techniques (above all the Göttingen minipig) (Rozkot et al., 2015).

The following remarks on the minipig refer to the Göttingen minipig, unless otherwise specified.

Biological data of the minipig

Some important biological data of the minipig which are relevant to feeding in some cases are summarized in the following table.

Table 1: Biological data of the minipig relevant to feeding (according to Bollen et al. 2000 and Weiss et al. 2014)

Breeding maturity:	5-7 months
Sexual maturity	4-6 months
Oestrus cycle:	14-19 days
Duration of oestrus:	approx. 3 days
Gestation period:	112-114 days
Number of piglets/litter:	5-8
Birth weight:	400-600 g (up to 1000 g in larger breeds)
Weaning age:	28-35 (50) days
Life expectancy:	10-15 years
Body temperature:	37-40°C
Respiratory rate:	approx. 30 (excitation up to 300) breaths / minute
Heart rate:	approx. 80-100 (excitation up to 140) beats / minute
Feed intake	approx. 2% of body weight (dry complete feed)
Water intake:	30-120 mL/kg BM/day (depending on feed quality and housing conditions)

Feeding and feeding techniques

General information on feeding minipigs

Göttingen minipigs are diurnal animals and have a marked resting period during the dark phase. If minipigs have free access to feed, food consumption takes place preferentially in the afternoon and during the evening hours; water intake follows food intake with a delay of about one hour (Oldigs 1986).

By contrast, other minipig breeds, such as Munich miniature swine (Troll), consume about half their daily food energy intake in the dark phase when housed in pairs (Musial et al. 1998). Behavioural differences must be taken into account where necessary for the design of the experiment.

The feed may be given in solid form (pelleted, granulated or expanded, water content about 10%), as a mash (water content about 50%) or a soupy texture (water content > 80%).

Expansion of feed enhance the digestibility of the feed by a higher gelatinization degree of the starch. Feed given in mushy or liquid form also improve the acceptance and digestibility of the feed. However, this effect is generally rather undesirable in adult minipigs particularly in the maintenance phase.

Furthermore, mushy and liquid feed carries a greater risk for microbial spoilage and requires stricter feeding management, in which it is absolutely essential that the feed is prepared fresh each day and that any leftover has to be removed from the trough not later than two hours after the feed was provided.

It is generally not recommended to give feed in the meal form because of dust formation and losses caused by spillage.

It can be concluded that feeding pelleted complete feed is generally recommended in the minipig.

Various commercial producers offer complete feed for maintenance and also for breeding and rearing of minipigs (see Table 2).

Table 2: Range of variation in content of main nutrients in some commercially available feeds for minipigs

Feed	**Crude protein [%]**	**Crude fat [%]**	**Crude fibre [%]**	**Metabolizable energy (ME) [MJ/kg]**
Breeding feed	15.5 – 17.5	2.5 – 4.0	4.5 – 7.0	11.5 – 13.0
Maintenance feed	13.5 – 16.0	2.5 – 3.5	6.0 – 14.5	10.5 – 12.2

Fixed troughs that are easy to clean (e.g., troughs for dog kennels) or replaceable troughs are suitable as feeding installations.

A faster increase in body weight (50–60%) and higher feed intake is seen in female minipigs than in males when fed *ad libitum* (Bollen et al. 2005).

During maintenance the daily energy intake should be close to the fasting metabolic rate to avoid excessive weight gain and obesity. Data on the fasting metabolic rate of Yucatan minipigs have been published by Parsons et al. (1990):

Sows: 93 kcal/kg $bw^{0.75}$

Boars: 158 – 126 kcal/kg $bw^{0.75}$

Maintenance: sows: 116 kcal/kg $bw^{0.75}$

It can be assumed that the fasting metabolic rate of other minipig breeds with similar body weights lie within the same order of magnitude.

Since minipigs do not regulate their feed intake, the daily feed allowance should be restricted (Bollen et al., 2005). In practice, the daily ration is usually spread over 2 mealtimes, but may also be given more frequently. Feeding should take place at regular intervals. Animals housed in groups should be fed individually as far as possible, so that the individual allocation of rations is ensured and stress caused by food envy is avoided. Recommendations for the Göttingen minipig can be found in table 3.

Table 3: Body weight development and resulting quantities of feed (dry complete feed, maintenance) for rationed feeding of the Göttingen minipig (Ellegaard, 2013)

Age (months)	Body Weight (kg)	Male minipigs	Female minipigs
2-4	5-9	240	220
4-6	9-13	240-300	220-280
6-8	13-17	300-340	280-320
8-10	17-21	340-380	320-360
10-12	21-25	380-420	360-400
>12	25-35	420-600	400-600

It is important to adapt the quantity of the feed to the nutritional status, which can be assessed regularly e.g., by means of the Body Condition Score (Fig.1) and recorded by regular weighting of the animals.

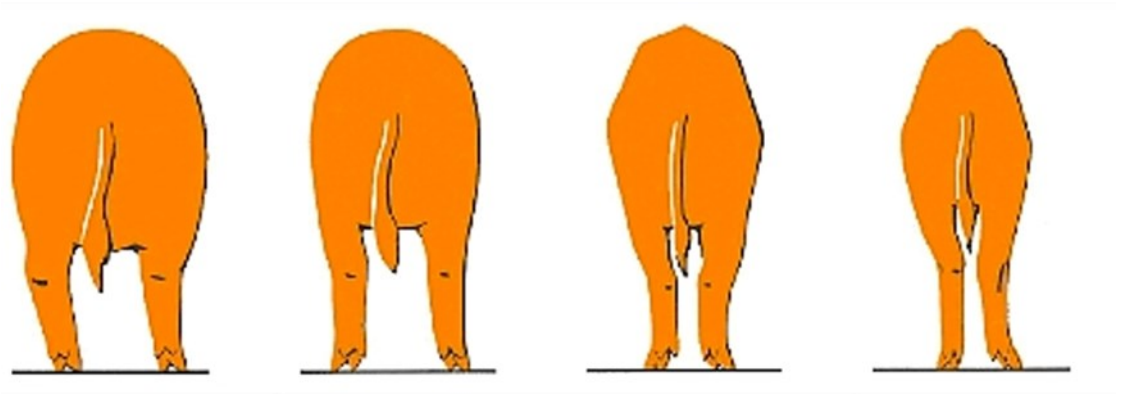

Figure 1: Nutritional status in minipigs (modified according to Bollen, 2001)

Minipigs between 2 and 12 months of age should gain about 500 g per week; The weight gain should be reduced to 250 g/week in the second year. The maximum weight of 40 kg should be reached at the age of 20 months (Ellegaard, 2019) (Fig. 2).

The actual food consumption is influenced by various factors, such as age, weight, gender, health status, activity, single vs group housing, ambient temperature, air change rate etc. When the animals are housed on bedding material, mats or underfloor heating, the energy consumption for maintaining body temperature is reduced, which is also reflected in the demand for feed (Ellegaard, 2013).

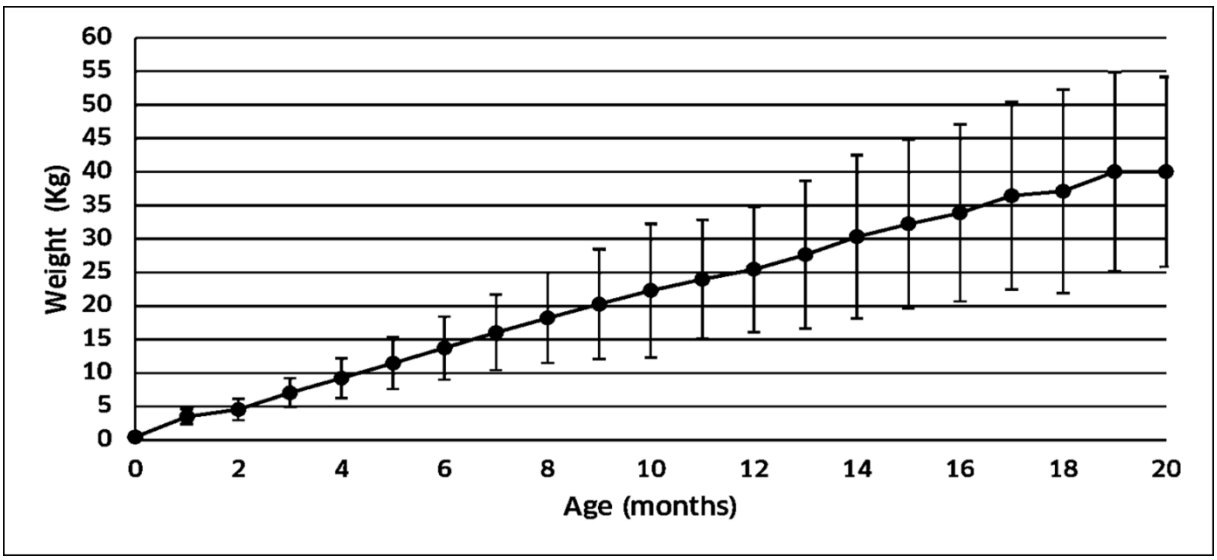

Figure 2: Growth curve in Göttingen minipigs (Ellegard, 2019)

The daily feed quantity should be adjusted within a range of ± 20-40%, if the body weight development shows a marked deviation from 'normal' growth curve.

Drinking water must always be fresh and freely accessible. It is usually provided via self-watering systems. These are preferably nipple waterers installed at the shoulder height of the pig. The nipples may be pre-installed at various levels or be individually adjustable, where the height has to be regularly adjusted to the growth of the animals (Ellegaard 2013).

Water intake is strongly influenced by the water content of the feed. When dry feed is used (e.g., pellets) the normal daily water requirement is 80-100 mL per kg body weight (Bollen 2001). Other factors, such as housing conditions, pregnancy, lactation etc., also affect the water intake (Sinclair bio-resources 2010).

Special feeding requirements of minipigs in the various life phases

The values listed in the following sections on feeding requirements, the feed quantity and composition are based largely on empirical observations. Experimentally determined values are still not available.

Pregnancy

During pregnancy, breeding sows are fed on a breeding diet at a level of 0.6-0.8 kg/d. In the last trimester, this is increased by 100 g per day, although the daily ration should be reduced to 400-500 g a few days before the scheduled date of farrowing.

Lactation

After farrowing, the quantity of feed for the dams is increased to 1.1 kg breeding feed per day (see Table 3 for composition) and then by a further approx. 90 g each day. However, the quantity of feed is dependent on the energy density and nutrient content of the respective diet. It is important that the ration is quickly eaten in each feeding session. Directly after the birth,

mushy or liquid feed is recommended to promote food intake. If the feed is not completely eaten, the remaining feed should be removed after an hour and the subsequent quantity of feed reduced accordingly; about one week after farrowing sows can also be fed *ad libitum*.

Growth

From the second week of life, the piglets are provided with small quantities of solid feed (e.g. breeding feed) at a feeding place separated from the mother. This helps them gradually prepare for the change of feed after the suckling phase, to activate the necessary digestive enzymes and to reduce weaning stress. A complete change to solid feed (piglet starter or breeding feed) is made when the animals are weaned at the age of about one month. The transition to solid feed increases the risk of diarrhoea in young piglets, about one week after weaning. For this reason, the feed should be introduced gradually. In the third month, the animals can be gradually switched to maintenance feed (Glodek & Oldigs, 1981).

Maintenance

Minipigs tend to become overweight, so a low energy density of the feed is advisable. This is taken into account using a maintenance feed with a high crude fibre content of at least 10-14%. Indigestible crude fibre not only dilutes the nutrients, but also reduces digestibility of the organic substance, thereby allowing for an easily manageable energy restriction. This feed should also be rationed and not provided ad libitum in order to prevent excessive food intake and consequently obesity.

Complete feeds for maintenance and breeding of minipigs take into account the differing requirements and allows for good standardization in feeding (Bollen 2001).

Recommendations for restricted feeding regimes and possible daily rations can be found in Section 3.1 and Table 3.

Feeding in experiments

The feeding requirements in an experiment may differ from physiological requirements depending on the research in question. In this section only a few examples of the impacts of certain conditions can be given.

In principle, the following conditions should be considered:

Trained, level-headed staff; the animals should be cared for by the same persons before and during the experiment.

Any changes in feed required should take place gradually over a reasonable period of time (about one week) and should be avoided before and during an experiment.

The consumption of feed is completed within a few minutes when a restricted feeding regime is applied. Following a meal, the animals need to rest. Any manipulation required by the experimental design should be timed to fit in with the feeding regime.

If single housing is required by the experiment, the accommodation of a social partner in an adjacent box with visual, olfactory, and auditory contact is necessary. With single housing, the

energy requirement for maintenance of body temperature is increased, which has to be considered under the aspect of housing and feeding conditions (Ellegaard 2013).

A fasting period of 8-12 hours should be observed before any surgical procedure; it is also important to remove the bedding material (GV-SOLAS Committee for Anaesthesia and Analgesia 2012).

Feeding is accompanied by a rapid rise in blood pressure and heart rate; the blood pressure quickly returns to normal values, but it takes several hours before the heart rate returns to baseline values (Stubhan 2008). This must be taken into account in the planning and evaluation of an experiment.

Feeding during transportation

It is recommended that minipigs are provided with fresh vegetables and/or fruit during transportation. In this regard, please note the GV-SOLAS information sheet on the use of non-standardized feed in laboratory animals: *Einsatz von nicht standardisierten Futtermitteln bei Versuchstieren* (2012).

Water bowls should also be made available and regularly filled with fresh water (EFPIA: Laboratory Animals – Good Transportation Practice)

Further information on feeding and general transportation conditions for Göttingen minipigs are provided by Raaschou-Nielsen (2012). In principle, the regulations on the protection of animals during transport (TierSchTrV; (EC) No 1/2005) always apply also to minipigs.

Enrichment

For animal welfare reasons, minipigs must be provided with a sufficient quantity of suitable material for encouraging activity and stimulating their natural behaviour. Aside from various “toys”, the availability of straw ad libitum, for example in the form of bedding and/or in feeding racks, can also be seen as enrichment (Ellegaard 2017). The intake of straw allows an additional form of activity for the animals and reduces “feeling of hunger” and hence associated restlessness between meals. Hay and/or straw may also be offered in racks with narrow wire mesh from which only individual stalks can be plucked, thereby prolonging the activity.

Some of the pelleted feed may also be scattered directly on the floor or in the bedding (straw) as enrichment to encourage the activity of the pigs.

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