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The physiology and complications of heat in sows.

Az anyakocák hőfiziológiája és szövődményei.

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Abstract

The following paper is investigating the different influencing factors throughout a female pig's life. The topics mainly focus on the reproductive aspects. Starting with the physiology and anatomy of the sow's reproductive tract. The mechanisms of the oestrus cycle with all it's challenges and practical points that ensure a healthy and fertile herd. Especially the farm's management and continuous controlling of feedstuff, semen and stable hygiene are from great importance. One of the biggest errors of keeping breeding sows are the returns to oestrus resulting on the one hand in economic losses and on the other hand in a poor life quality of the sow. Raising a healthy breeding pig requires a balance between animal welfare, a professional farm management and veterinary expertise.

Absztrakt

Az alábbi dolgozat a nőivarú sertések élettanát befolyásoló tényezőket vizsgálja, főleg a szaporodás-biológiai szempontokat helyezve előtérbe. Áttekinti a koca nemi traktusának anatómiáját és élettanát. Bemutatja az ivari ciklus mechanizmusait annak szakmai kihívásával és gyakorlati voatkozásaival, amelyek biztosítják az egészséges és termékeny nőivarú állományt. Különösen fontos a takarmány, a termékenyítéshez használt sperma és a tartáshigiénia folyamatos ellenőrzése. A tenyészkocák életében az egyik legnagyobb gazdasági veszteséget a fogamzás elmaradása. amit a visszaivarzás jelez, ugyanakkor ez a koca általános életminőségére is utal. Egészséges tenyészsertések neveléséhez nélkülözhetetlen az üzemi menedzsment, az állatorvosi munka együttműködése, ahol az állatjóllétre is figyelmet fordítanak.

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Abbreviations

FSH	Follicle stimulating hormone
LH	Luteinizing hormone
CL	Corpus luteum
PGF2	alpha = Prostaglandin F2 alpha
eCG	Equine chorionic gonadotropin
hCG	Human chorionic gonadotropin
RTU	Real time ultrasound
ACTH	Adrenocorticotropic hormone
HPG	Hypothalamic-pituitary-gonadal axis
HPA	Hypothalamic-pituitary-adrenal axis
DON	Deoxynivalenol
ZON	Zearalenon

I. Introduction

World population is rising and so are the nutritional demands of the humans arise as well. Pork meat is an essential nutritional source in many countries. To maximize the animal breeding outcome, it is important to meet the animal welfare aspects. If these aspects are corresponding with the pig's demands the maximal profit can be achieved which is an economic benefit. Having the ability to fulfill the swine's needs it is of high importance to understand the physiological background of porcine reproduction.

Thus the four oestrus cycle stages are part of the needed basic knowledge. Pigs are known to be sensitive animals and so professional work must be done starting already before farrowing. The embryonal stage is paving the way of the further reproductive life and therefore the fertility of the animals. Moreover the reproductive performance is depending on the puberty which is a highly sensitive phase of the young sow and depending on the farm's management and awareness of the responsible person keeping the animal. In a successful breeding facility another critical point is the detection of heat which can be done in different ways. For heat detection on the one hand there are the convenient ways like performing a back pressure test and on the other hand a more complex way like using ultrasonographic devices can be used. Moreover the understanding of physiological changes during heat is necessary to be able to detect external changes in the means of observing the characteristic vulvar discharge or reddening of the vulva. It has to be taken into account that those parameters are influenced by the age of the pig as well.

When it comes to professional breeding of pigs many potential obstacles must be faced and prevented. Especially returns to heat are common complications that can be caused by many different influencing factors. To avoid problems like these an optimal stable management and feeding practice is required and need to be monitored continuously. Toxins like mycotoxins are a big topic when it comes to heat related issues.

Another important points are the boar and semen management which are used for artificial insemination. Those have a huge impact on the outcome of the heat detection and in non-successful cases on the reason for a return to heat.

The following chapters will summarize all parameters that need to be focused on in order to ensure a healthy pig in heat.

II. Physiology and anatomical aspects of the female reproductive system

Maximizing the reproductive efficiency of female pigs is of major economic importance as the demand for reproductive success is in steady increase during the last decades.
Therefore, understanding the reproductive system is a crucial key.
The major anatomical structures and physiological aspects of the reproductive system consist of the internal and external organs which will be discussed briefly.

a. Anatomical structures

The internal portion is located in the lumbar region of the abdominal cavity and contains the paired ovaries which are the primary organs of reproduction. Sows are the only farm animals having lobulated ovaries due to the developing fertilizable ova (mature females gametes). Sows are polyoestric animals which means they have several cycles per year. For this procedure the ovaries are the main organs. The paired organ is of endocrine and cytogenic nature, so they produce steroid hormones (steroid genesis) and cells (gametogenesis). [1]
Progesterone and estrogen are the hormones produced in the ovaries which are needed for the development of the genital tract and the early migration of the embryo. They are covered by the oviduct containing infundibulum. Each ovary is connected with one uterine horn which will be fused together forming the uterus. The well-developed muscle layers are essential for propelling the spermatozoa to the oviduct, creating space for the growing embryos and also for the hormone production. In sum the uterus has four muscular layers with the forth one building the outer surface. [2]
The uterine tubes (so called oviducts) are paired and convoluted organs which are the place of fertilization of ova by the spermatozoa. [1]
The uterine capacity determines the litter size as the embryos will be implanted here.
The caudal projection of the uterine is the cervix which is smooth muscle sphincter that is closed unless there is a present pregnancy or parturition going on. It is dilated during heat and constricted during gestation or if no heat is present.
Within the pelvis right between the uterus cranially and the vulva caudally the vagina is located. It is connected with the inner cervix.

As the bladder is emptying into the vagina the immunoprotective function of the vagina is very important. The vagina is also the birth canal. [3]
On the external side of the genital tract the vestibule and vulva are found. The vulva consists of a right and a left labia which meet at the dorsal and ventral commissure. In gilts the vulva is rich in bloodvessels which can be swollen or the color of the vulva can be changed during time near estrus. The vaginal smooth muscle layers of the female pig consists of an inner circular and outer longitudinal manner which will play an important role in artificial insemination. [3] It is also important to know that the bladder is emptying into the vagina on the vagina's floor roughly 5 cm from the external opening to avoid inserting a spiral artificial insemination catheter into the urethral orifice. [2]

The vestibulum is the connection between external genitalia and the vagina. Female pigs additionally have short blind ending sac ventral to the urethral opening, the so called sub urethral diverticulum. [3]
Thus, in female pigs, both urination and birth occur through a single urogenital opening.

b. Oogenesis in female porcine, preantral follicles

During the prenatal life the primordial germ cells migrate in the fetus from the yolk sac to the growing ovaries. [2] When taking a closer look - the oogenesis describes the development from the primordial germ cells into dictyotene oocytes in primordial ovarian follicles – this phase is the gonadotropin dependent period. During this time of maturation the follicles can be classified in three phases: primordial germ cells, primary follicles and secondary follicles. [6]
Those phases are differentiated in size, gonadotropin hormone dependency and the type of granulosa cells. Before reaching day 80 of gestation the levels of LH (Luteinizing Hormone) and the FSH (Follicle Stimulating Hormone) are rather on a lower level or sometimes not even not detectable. FSH will elevate after day 80 and remain elevated until birth. [5]
The quantity of produced hormones depends on the development of the fetal pituitary gland which starts after day 50 and will continue its differentiation from day 70-110. FSH and LH secretion is promoted by the Gonadotrophin-releasing hormone (GnRH) which is synthesized and secreted from the hypothalamus. [7]

Reproductive organs such as the ovaries can influence the GnRH release by producing estradiol and progesterone (steroids) and inhibin hormones (peptides).
Furthermore the basal release of GnRH is controlled by neural inputs of the hypothalamus, this release is of pulsative nature.
Estrogen levels are low during the first 5-6 prenatal weeks first but after day 95 the estrogen will significantly increase. [2]
The germ cells will be surrounded by a single layer made of follicular cells which will finally be an ovum later. The size of one primordial follicle is approximately about 35-100 micrometer. When having a look at the hormonal influence the primordial follicle is gonadotropin independent. [3]
Through rapid and intense mitotic division, the oogonia cells develop into clusters. Inside those clusters some cells undergo meiosis rather than mitosis and develop into primary oocytes but will not go through all stages of meiosis and arrest in a stage instead at diplotene (dictyate) stage. The diplotene stage is mostly recognized at day 20 post partum. The primary oocytes with surrounding follicular cells are primordial follicles that will be arrested in this stage until puberty is reached, then the ovarian cycle will start. The rule of thumb is that gilts experience puberty around the age of 180 days. [6] The morphology of the primary follicle is similar to the primordial germ cell, but it is bigger in size and the growth of the zona pellucida is notable. Moreover the primary follicle is gonadotropin dependent. If the primary follicle has started its development this progress cannot be interrupted and so the secondary follicles will develop. [1]
The number of granulosa cell layers is increasing and its growth is gonadotropin dependent. Also the metabolism will be stronger and when the primary follicle becomes a secondary follicle lipid droplets are appearing in great number. Those lipid droplets are typically round and dark in primordial and primary follicles but will be bigger in size and darker in color when turning into a secondary follicle. [3]
There are FSH and LH receptors in the theca and granulosa of the secondary follicles that are able to response to the produced hormones. It can be said that with increasing age the hormone receptors are increasing too. The size is 300-400 micrometer in this stage of development. In the secondary follicles cortex granules are produced continuously and will be fused to clusters. [8]
Around birth the fetus has a so-called resting pool with around half a million follicles (420.000 primordial follicles) in resting stage. [7]

When reaching the age of approximately 20 weeks of age the primoradial follicles will turn inro recruitment stage which is the first stage when the resting pool will become growing a pool with a decreased number of follicles. [7]

c. Ovarian maturation, antral follicles

During this stage of development the antral follicles will mature. The development of the early tertiary follicle (antral follicle) is marked by the increasing number of granulosa cell layers and the theca cell layer. Another expression for tertiary follicles are Graaf follicle or vesicular follicles. In contrast to the primordial follicles – the antral follicles are dependend on gonadotropin. [9]

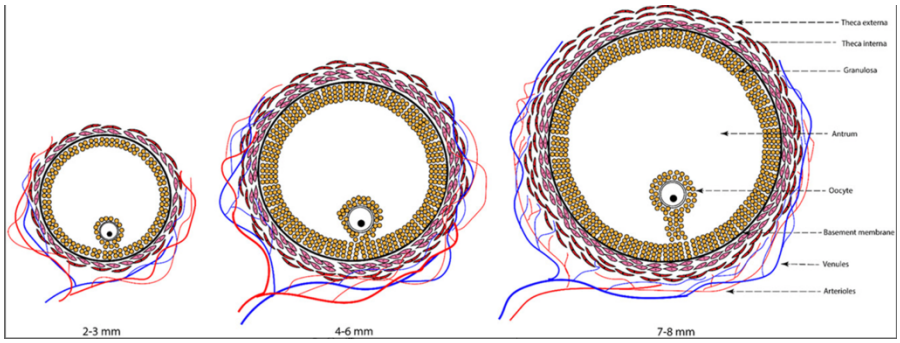

Figure 1: Follicles in different stages of development [10]

Figure 1 shows the physiological development of follicles in a healthy pig. From 2-3 mm in size until the final stage (ovulatory stage) of 6-7 mm is reached. The figure also shows the extension of the antrum, bloodvessels, theca cells and granulosa cells.

The term antral refers to filled antrum (cavity) with antral (tertiary) follicles. The tertiary follicle has a special morphological feature as there is an internal and external layer. The external layer mainly consists of connective tissue whereas the internal layer is made of vessels and thecal cells. The internal granulosa cells are responsible for secreting glycoproteins. This will form the zona pellucida which acts like a protective shell as the zona pellucida is completely surrounds the tertiary follicles. So with the growing granulosa cells in the proliferating cells there is an increase in FSH which leads to activation of LH receptors on the theca interna cells. This process will promote the secretion of estrogen and androgens. [5] Both FSH and LH are essential for the successful maturation of the follicular maturation and growth.

When the antral follicles reach a size of 2-3 mm they rely on FSH and follicles having reached a size of more than 5 mm they are dependent on LH. [8]
Next to FSH and LH estrogens will be produced by the granulosa cells as well. The estrogen is responsible for the increase of FSH and LH receptors which will additionally promote the granulosa cell replication and secretion. This process is also termed as 'local positive feedback effect' of estrogens which is needed for the production of the ovum and ovulation later. [3]
The estrogen in developing follicles is responsible for the preparation of the follicle and hypothalamic-adenohypophyseal axis needed for the later ovulation.
In contrast to the positive feedback of estrogen to evoke the LH which is then needed for starting the ovulation – inhibin has a negative feedback on FSH release from the adenohypophysis. It does not suppress the LH secretion. Inhibin is released from granulosa cells of the multiple growing follicles. Its effect will suppress the growth of more follicles and so prevent inappropriately large litter sizes. [5]

III. Mechanisms during porcine estrus cycle

Getting in heat is a crucial factor in the pork production as it's the indicator of the sow's future productive potential of the pig.

a. The definition of heat and general facts about the pig's estrus cycle

The term 'heat' refers to the time during the estrus cycle when the sow reaches the maximum sexual receptivity and fertility and is able to get pregnant. [3]The premise for establishing an functioning cyclic ovarian activity and therefore getting into heat refers to a successful puberty at the age of 5-7 months depending on the genetics and breed as well. [11] Important factors for experiencing puberty is the nutritional level, social life or the boar contact. The majority of sows are experiencing their first estrus circa 1 week after weaning. An important term when it comes to heat is the 'standing heat' which mainly describes that the female pig is receptive and stands for mating. The length of standing heat depends on the length of the heat period. [5]

During the sows 18-21 days long estrus cycle the duration of heat is approximately 1-2 days. In this time period the pig can get fertilized via artificial insemination (AI) or natural breeding.

The sow is constantly cycling throughout the whole year which can only be interrupted by pregnancy and lactation, diseases or age.

It can be assumed that females are ovulating at a lower rate of follicles during their first estrus and they are less fertile than during the later following estruses. [12] An interesting fact is that in wild pigs the main mating season is in the early winter months. [13]

In general the estrus cycle of female pigs consists of four stages: proestrus, estrus, metestrus and diestrus. As a rule of thumb, it can be concluded that pigs will have their first estrus at about 170 to 210 das of age, of course depending on the external factors which will be discussed closer later. In these four phases different hormonal changes can be measured. [3]

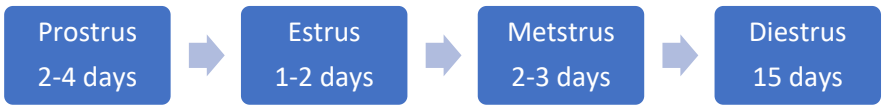

Figure 2: Phases of estrus cycle

Proestrus and estrus are defined as follicular phase (5-7 days) whereas the luteal phase (13-15 days) contains the metestrus and diestrus which makes 18-21 days in total. Estrogen is the main hormone responsible for sexual receptivity. [9]

The follicular phase is marked by the formation of small antral follicles into large preovulatory follicles and takes place during the end of luteal phase and ovulation. [7]

During proestrus (day 17-21) there is a pronounced secretion of FSH and estrogen which is important for the further development and preparation of estrus. Also some short pulses of LH secretion can be measured. Also there is a significant increase in size. [9]

When reaching estrus (day 0-1) the follicle has become mature and there is a peak in FSH, LH and estrogen secretion. [7]

This peak will be the reason for the rupture and finally the ovulation. In general the ovulation takes place in 1-2 days after the estrogen peak. 15-20 eggs are ovulated per cycle. [5]

Directly after ovulation the luteal phase will take place. In the luteal phase the CL will increase the progesterone level which will be important for maintaining pregnancy.

In this stage the sow is no longer receptive and FSH, LH and estrogen are decreased. If no fertilization has been recognized around day 12 the uterus will secrete PGF2alpha which causes luteolysis that resulting in a stop of progesterone secretion. Therefore a new estrus cycle will start. [7]

In metestrus (day 2-5) progesterone production will be high when the final CL has been formed after ovulation. [14]

The fourth and longest of all phases is the diestrus (day 6-18). In this period the pregnancy will be recognized and the progesterone level will rise starting from the twelfth day of gestation. [9] [5]

b. Behavioral changes during heat, sexual behavior

Before going into the next topic, it should be highlighted the sexual behavior depends on the housing and use of the sows. [3] Large scale farming differs to outdoor keeping or wild animals as the housing systems and management have a big impact on the sexual behavior and so does the use of the animal. Sexual behaviors are driven by the hormonal changings in the follicular phase. [11]

Also Testosterone has an impact on the pig's libido which is secreted from degenerated follicles where androgens and androstenedione are produced. [5]

When the sow is getting in heat many different behavioral changes can be observed.

If the sow is kept in a semi - intensive conditions (housing where the animal is able to walk, together with other female pigs in a group) an increase social activity can be observed. Also if there is a boar in the pen the female in heat will search for contact with him spending much time in standing posture. [15]

With increasing the contact to the boar the HPA axis will be stimulated which has an influence on increased cortisol secretion and the sow will be stressed. [9]

This HPA axis effect can result in a shortened cycle and more number of eggs. But it must be taken into accountant that the sow should not directly be in the same pen as the for longer period of time as the animals can easily get used to the boar's presence leading to a decreased oestrus detection rate. [22]

The most efficient technique of sow/gilt-boar contact is a daily contact of 10 minutes. In conclusion it can be said that the boar contact definitely has impact on the reproductive productivity. [15]

Moreover there are some typical behavioral pattern that can seen before the female gets into heat. Nervous and quick, rushing movements can be detected when walking into the stable. This can especially checked if kept with other females in a pen that are in dioestrus as those pigs will stay calm and not react to slight disturbances. While females in proestrus will get up and check if any male animal arrives. [16]

When the boar enters the pen the pig being in heat will directly go there and start sniffing the anal region and preputial regions and searching for a close contact with the male. Also head to head contact, pressing noses (nosing), ear biting, showing interest on genitals and mounting attempts can be seen. [22] Furthermore unusual grunting and chanting can be heard. Females not being in heat will try to not get in contact with the boar and rather aggressive behavior is described. [17]

One of the most important mechanisms in the reproductive 'communication' between pigs is the pheromonal signaling which is also called olfactory communication where the animals totally rely on their sense of smell. [15]

A steroidal pheromone is a chemical molecule that is synthesized by an animal and excreted externally with the goal to increase the behavioral response of the other animal of the same species. [31]

Pheromones that have an influence on sexual activities or sexual receptivity, are defined as ‘sex pheromones’ or ‘specific boar pheromone’. Moreover pheromones are stimulating the sows’ sexual behaviour and reproductive cycle. [4]

It is not a hormone but similar and they are produced mainly in the submandibular gland and the parotid gland secreting salivary steroids as they are carries in the saliva of the boar. The main saliva pheromones are androstenone and androstanol. These two stroids are also the ones that provoke estrus behaviour (so called boar behaviour) and are essential for the female reproduction and estrus detection. [5]

The saliva steroids bind to the corresponding binding or carrier proteins which are part of the vomeronasal organ and nasal mucosa of the sows. Until now only four proteins have been found in the nasal mucosa and the vomeronasal organ which are the following proteins: Von Ebner’s Gland Protein, pheromaxein, odorant binding protein and salivary lipocalin. Without the interplay between the steroidal hormone of the boar and the binding protein of the sow no chemical way of communication is able to take place. [18] When having a closer look on the anatomical structures it must be highlighted that the porcine olfactory bulb possesses approximately 11000 glomeruli which makes the pigs olfactory system superior to those of humans. [19]

To summarize the amount and quality of the boar’s ability to produce pheromones has a big impact on the sows sexual behaviour. In a positive way of course the pheromones stimulate the sow and can decrease the aggressive behaviour in prepubertal swine. [4] In freshly regrouped pig groups a small dose of andosterone can be used as its said that andosterone can lower the agonistic behaviour but on the other hand its also possible that it can increase the aggressive behaviour in prepubertal pigs when used in a wrong dosage.

In this case a small dose was defined as 0.5 micrograms sprayed on the snout. [20] It is also possible to use artificial, readymade sprays which is similar to the boar’s saliva. [15]

In cases of unsuccessful stimulation of puberty the usage of a boar hormonal products can be used via direct injections.. The administration of 1000 IU eCG (equine chorionic gonadotropin) or a mixture made of eCG and hCG (human chorionic gonadotropin).

A beneficial side effect of the exogenous use of those hormones is the shortened and often better synchronized post weaning oestrus. [21]

If the first oestrus was missed by the farmer and the exongeous gonadotropins were used the response to the administered drugs are known to be rather poor and not sufficient. [14]On the other side if the oestrus should be suppressed altrenogest can be fed orally. Altrenogest has an effect on the development of the ovarian follicles as it has the same functions like progesterone. Therefore the result is a suppression of the endogenous gonadotropin production and creates a negative feedback on the LH release. As a final result no oestrus will follow. [21]

c. Anatomical changes and signs of heat

Several changings can be observed in the female pig when being in heat which is an important tool for the mating management as its shows the suitable time of insemination. The expression and intensity of shown signs are influenced mainly by the age of the animal. [5]

The most obvious signs that can be seen in gilts is the reddening and swelling of the vulva which shows that the pig is coming to heat. Studies have shown that the temperature when taking vaginal temperature or checking with infrared thermograph during estrus the temperature is decreased by approximately 0.26°C.[11] Increased estrogen levels will be the reason for the swollen vulva as the hormone will stimulate the blood flow in direction in the genitals. The vulva lining can be in a reddish color as well. In older pigs the swelling will not be so prominent and sometimes can even be absent thus the age and reproductive state of the sow has an impact on that external changing. [17]

Next to the swollen vulva the changing in the discharge is a hint of being in estrus. When pulling the labia apart and down the clitoris it can be seen which is likely to be rather small in gilts due to the small size of the vulva. [9] A bright red color can be detected when examining this region.

If the pig is not in heat the clitoris is flat with a pinkish color. When the sow is in standing heat a sticky mucoid discharge will be produced.

If the discharge wants to be checked there is an easy method using two fingers (thumb and index finger, use gloves!) and putting some discharge on them and then pressing the two fingers together and then draw them apart slowly. [9]

Depending on the stage of estrus cycle in which the sow is in specific signs can be observed which are presented in the figure below.

Table 1: Characteristic changes during heat [9]

Characteristic changes during heat			
Proestrus	***Oestrus***	***Diestrus***	***Anestrus***
- Estrogen is the dominant hormone - increased blood flow throung vaginal mucus membranes due to estrogen --> reddish, pinkish colour - moist, shiny mucus mucus membranes - signifinact swelling of the labia - restlesness behaviour - decreased feedintake - wont tolerate mounting - secretion rather thin	- follicles reach maximum size - ovulation happens - decrease in size and pinkish color of labia - secrentions rather honey colored, more cloudy, - positive back presure test	- complete flat labia - wrinkled labia - no tolerated mounting	- Progesterone is the dominant hormone - building the corpus luteum from ovulated follicles - labia pale and wrinkled - regression of the corpus luteum if no fertilization has happened - new follicles can grow

Using this technique, the consistency and also color/transparency of the discharge can quickly be checked. In the beginning of oestrus the discharge is oily and clear it is a sign for standing heat. Whether it becomes sticky when the pig is reaching the phase of standing heat. [17]

Additionally, to external changes also internal changes take place when getting into heat. Due to the increased estrogen and oxytocin and decreased progesterone levels myometrial contraction occur. [7]

Estrogen tends to have big impact on the peristalsis from isthmus uteri towards the uterine body. These contractions are essentially needed for the transport of spermatozoa from uterine body to the fallopian tubes. [5]

One of the most important tools in porcine reproduction is the heat detection. All previously mentioned behavioral pattern, external signs and mechanisms must be checked when it comes to heat detection. [9] [58]

d. Heat detection

To ensure the best outcome in porcine reproduction the tool of detection female pigs being in heat and detecting the perfect timing for insemination or breeding is essential. Changes in behaviour, the external genital organs and uterine changes are building the foundation of heat detection. There are different techniques that can be used for detection. On the one hand there are very practical and handy ones that can be applied by the farmer and on the other hand there are more complicated ones relying on ultrasonography and comparing body temperatures. Both ways of measurement will be screened below. [9]

Next to detection the stimulation of the sow is essential too as without stimulating the sow some key reactions of being in heat are likely to be missed. Some practical ways of stimulating the pig will be described below. [15]

When having a look at the heat detection that can be used on field, the back pressure test (BPT) is probably the most important and most often used. A positive pressure test determines the begin of the heat. The triggering point during the BPT is the bond between alpha androstenone and receptors sitting in the nasal mucosa. [22]l As already mentioned previously the nasal mucosa (regio olfactoria) is essential for being able to detect pheromones and the boar. Those receptors are influenced by oestrogen. Androstenone will be released by the boar when doing chewing movements as the steroidal class pheromone is secreted by the parotid gland. [23] Moreover the sound of the boar is a stimulating factor too so olfactory and auditory stimuli are of big importance. [22]

To achieve a successful BPT the adequate stimulation of the pig is necessary.

When performing this test the person doing it has to gently press the pig's lower back (back, flank and underline, kidney region) with using flat hands. [24] The BPT is positive if the sow is in heat, the back will arch back and muscle contractions can be felt in the legs and back showing the female is ready to be mounted by a boar. In case of a positive BPT the riding test can be performed which means the performing person is carefully sitting on the pig's back. In case of heat the sow will allow the riding test and stand still. [25]

Moreover when facing the practical techniques of stimulating the sow to further detect heat some on field methods have shown the best outcome. As already mentioned, the stimulation and pheromones play a crucial role thus the direct contact with the boar is a very good way of checking the sows behaviour. If she is in heat she will reach out for contact with the boar. [24]

Another way of stimulation is the flank pressure test where the performing person is standing lateral next to the animal and starts to gently press with one hand against the back while the other hand is pulling up the knee and massaging the flank. Another stimulation test is the flank gently massages where the person folds up the knee fold while slowly rubbing the teats which should calm down the sow. [9]

Next to practical methods also transcutaneous ultrasonography or real time ultrasonography (RTU) can be used for ovulation detection as the changes of the ovary can be screened. For the best imaging a 5 MHz transducer is advised. [26] It is beneficial to scan the pigs during feeding time. As the ovulation is a spontaneous process the interval between the first and the final ovulated follicle is from two to five hours. The start of ovulation can be detected when dark spots (follicles) are vanished from the screen approximately 40 hours after a positive heat detection. Also during ovulation the follicular fluid appears darker. It is not possible to count the follicles with transcutaneous ultrasonography. [27]

To achieve the best outcome it is essential to perform the scan minimum four times daily after heat detection. [27]

For general understanding of ultrasonographic imaging throughout the different oestrus stages a small summary is presented below: [26] [27]

Table 2: Ultrasonographic appearance [27] [26]

Oestrus cycle phase	Scan: Uterus	Scan: Ovaries
Luteal phase	• Homogenous appearance	• Only some or none dark spots, ovaries closer to bladder
Follicular phase	• Uterine horn sections visible	• Turgid follicles • Clearly visible contours • Cluster, small dark spots
Oestrus	• Uterine sections visible	• Cluster turn into formation of black spots

From the managemental point of view the best results can be achieved if the heat check ups are performed at a set time on each day so the best comparison can be made. [28] The best chance of successfully detecting animals in heat is when the check is done in the morning and using a mature boar but this should be done at least one hour after the morning feeding cycle. If the heat check is done too shortly after feeding the females will rather be focused on the food than on the boar which gives space for false scorings. Stables that are equipped with a tunnel-ventilation systems are good for walking the boar in the wind so the smell of the boar is spread over the whole area. [29]

IV. The influence of management and boar on heat and reproduction

Heat, stress, nutrition management, vaccination programs or the boar itself have a huge influence on the reproductive performance. In the following chapter the non infectious reasons will be discussed closer.

a. Farm hygiene and management

1. Stress

First of all stress is defined as any biological response to an internal or external threat (event) or adverse stimulus, or any event that disturbs the pig's physiological homeostasis. Any reason leading to stress is called a stressor. During the sow's life many different stressors can appear and defines the animal's quality of life and general said well being. [30]

What are stressors in a sow's life?

Figure 3: Stressors

Before starting off with the topic the basics of the physiology of stress will be explained. The background of the endocrinological reaction to stressors is the stimulation and triggering of the hypothalamic-pituitary-adrenal (HPA) axis and sympathetic adreno medullary (SA) system which is also called as 'fight or flight' reaction involving an interplay of nervous, immune and endocrine mechanisms which will maintain the stress response feedback. [31]

The ‘fight or flight’ reaction is also known to be the short acting stress response. [4] Either external or internal stressors act on the body’s limbic system, the cortex and further on the hypothalamus. [31]

Following the activation of the HPA mainly the corticotropin releasing hormone (CRH) will be will be released from the hypothalamus. Due to the CRH release the adrenocorticotropic hormone (ACTH) and beta endorphine will be secreted. [30] ACTH is also responsible for the secretion of cortisol which is one of the major glucocorticoids and also a specific stress hormone being involved in the longer acting stress response - reactions. [31] The activation of the SA axis takes place in case of acute stress and is an increased secretion of epinephrine and norepinephrine from the adrenal medulla (adrenal gland). [5]

Stress responses either short or long-acting ones have an impact on reproductive performance, metabolic and immunological processes. [31] It can be said there is a correlation
between animal welfare and stress. In the following chart the different impacts on the organ systems of short and long acting stress responses will be shown briefly.

Table 3: Impact of stress [32] [5] [5]

Hypothalmo-pituitary-adrenal axis	**Sympathetic adreno medullary axis**
• Increased glucose absorption from gastrointestinal tract • Increased hepatic gluconeogenesis • Cortisol blocks glucose metabolism • Defect in coagulation cascade, delayed wound healing • Peripheral tissues: skeletal muscles, heart, some areas in the brain • Acts on placenta → reproductive performance	• Increased bloodflow • Increased atrial pressure • Increased gluconeogenesis • Increased blood coagulation

• Downregulation of immune reactions	

When focusing on the reproductive system there are many side effects that are caused by negative stress. A very common stressor for sows is the regrouping after weaning. [32]

It is known that follicular development and ovulation are extremely sensitive to hormonal disbalances, the interaction of hormones of the HPA and HPG that are released in stress situations have a big influence on the oestrus, ovulation rate and further on the success of service. [32]

In 2008 a study was done by S. Einarsson, Y. Brandt, H. Rodgriguez-Martinez and A. Madej which should show influence of the social stress on estrus. During the study the use of ACTH for two days should simulate the regrouping in real life. Each sow got a jugular catheter to check the blood every tow to four hours. [30]

To successfully screen the growth of follicles and later ovulation the sow was checked with transrectal ultrasonographic imaging every four hours. [33] The outcome after administering ACTH in proestrus was a prolonged estrus, an abnormal follicular growth and disturbed ovulation. When the ACTH was given right during estrus a raised level of cortisol and progesterone was measured. ACTH in estrus does not only cause hormonal changes but also a change in the intraluminal environment in means of increased level of mucus in the utero-tubal- junction. [31] So to conclude it can be marked that simulated stress but of course also non-simulated stress causes a prolonged estrus interval and a disturbance in the follicular development. [33]

Especially stress between the third and 21th day of gestation the risk of returning to estrus is extremely high. [30]

2. Nutrition

Swine are monogastric omnivores and generally need a diet that is high in energy and lower in fiber – so lipids and carbohydrates are the major source of energy.

Female pigs used for reproduction have very high needs when it comes to adequate nutrition which must be met fully to ensure a healthy development and healthy litter.

When experiencing nutritional deficiencies, excesses or a lack of food serious consequences can follow when facing the reproductive processes. [4]

Next to quality issues of the feedstuff the hygiene and quantity play major roles in the reproductive performance as well.

The first aspect will be the influence of the quality on estrus and returning to heat due to nutrition. It is known that the times before and after ovulation has a need in energy and good quality nutrients to ensure a good shedding of ova and further a successful insemination.

Of course the amount and mixture of feedstuff depends on the age, weight and use of the sow. Animals kept for reproduction have the highest energy requirements during gestation and lactation.

If the female pig does not reach the needed weight and back fat during puberty the oestrus cycle can be delayed or the pig will not get in heat at all. In this chapter the focus is on growing gilts and the time of weaning to estrus until gestation. [34] It should be highlighted that the sow's lifetime reproductive and growth performance does start with the amount and quality of colostrum intake during the first hours of life.

As colostrum contains all needed nutrients (lipids, proteins/immunoglobulins, carbohydrates, bacteria, oligosaccharides) which are the main modulators of the intestinal environment and immune system of the piglet. So optimal colostrum ensure optimal body growth. [35]

What are the main nutrients that a sow needs? The following table shows an example of dietary needs: comparing a piglet to a sow ready for the first service

Table 4: Nutritional demands [36]

Content	**5-7 kg**	**135 kg**
NE content of diet (kcal/kg) (NetEnergy)	2,44	2,47
DE content of diet (kcal/kg) (DigestibleEnergy)	3,5	3,4

ME content of diet (kcal/kg) (MetabolizeableEngery)	3,550	3,300
Body weight gain g/day	210	867
Estimated feed intake and wastage g/day	280	2,933
Amino Acids, (total %)		
Arginine	0,75	0,32
Isoleucine	0,88	0,39
Methionine	0,94	0,21
Crude Protein	24-26	13,4
Minerals (%)		
Calcium	0,85	0,46
Phosphorus	0,70	0,46
Sodium	0,40	0,10
Iron (ppm)	100	40
Vitamins		
Vitamin A (IU/kg)	2,200	1,300
Vitamin D (IU/kg)	220	150
Vitamin E (IU/kg)	16	11
Vitamin K (mg/kg)	0,50	0,50
Riboflavin (mg/kg)	4,00	2,00

One successful way of making sure the breeding sow has a good nutritional basis is the strategy of 'flushing'. The so called flushing technique is based on ad libitum feeding and has the goal to increase the level of FSH and also maximize the LH pulses thus should increase the number and the size of the oocytes and therefore put the sow in a positive energy state. More ovulated eggs means bigger litter size. [3]

The strategy is based on feeding more than needed for maintenance around 2-3 weeks before service. In general the rule of thumb is flush feeding from weaning to breeding. [28]
The timing for flush feeding is best in the first and second cycle of the sow, as many studies showed that in those times the number of medium – large sized follicles was significantly increased. [34]

A very important enemy in pig nutrition is the mycotoxin contamination of feedstuff especially grains. At this point it must be highlighted that pigs especially gilts are extremely sensitive to those compounds. For gilts 1-3 ppm of contaminated feed would be enough to result in reproductive damage. [4] [38]

Mycotoxins basically mean 'toxic fungi'. Those fungi live as saprophyte on different organic matters. The mycotoxin itself is a toxic metabolite of the fungi. [37] The most common mycotoxins are Deoxynivalenol (DON) and Zearalenon (ZON or F2 toxin) which can be detected in mouldy hay, pellets or corn which is high in moisture. [38]

The problem is that the grains and corn can already be infected before harvesting. [38] ZON belongs to the family of Fusarium sp. Whereas DON are part of the B-trichothecenes. After ingestion of the toxic metabolites the toxins will cause immunosuppression, reduced feed intake and a decreased reproductive performance as the toxins have an influence on the sow's fertility. [13]

The special feature of ZON is it's potent estrogenic character. Which means that it binds to 17-beta-estradiol receptors and also influences FSH and LH. This bond will cause actions in the mammary tissue, uterus and massively control the synthesis of the sex hormones. [38] Those toxins are also found to be 'ovo-toxic' as their actions cause destruction to the DNA and inhibit ovarian functions due to direct oxidative damage. [39] The toxic metabolites are negatively interfering with the follicular development as

the follicles will experience atresia due to the apoptotic mechanism of action. The outcome is a disturbed ovulation and later no fertilization will take place. [40]

Another negative effect of the F2 toxin is that it can be transferred through the sow's milk to the suckling piglets leading to hypoestrogenism of the piglets. Clinical signs can be seen in both – younger and older pigs.

In the following table the most common clinical signs and effects of the toxic metabolites are presented:

Table 5: Impact of mycotoxins [41] [13]

Age	**Clinical signs**	**Effects**
Piglet	• Reduced birth size • Enlarged external genital organs • Nipples increased in size in male and female piglets	• Hypoestrogenism • Splay leg piglets
Gilt	• Inflammed, red vulva • Swollen vulva • Irregular oestrus cycle • Return to oestrus (regular return) • Enlarged mammary glands • Rectal, vaginal prolapse • Mummies	• Vulvovaginitis • Return to oestrus • Embryonic mortility increased • Pseudopregnancy (anestrus) • Ovarian atrophy • Ovarian cysts • Estrogenism

Another aspect in feeding beside the ingredients and toxins is the feeding strategy as this has a direct impact on the feed intake and later on the development of the gilt or sow. [29]

As there is a social hierarchy among a group it can happen that the animals ranked lowest are not able to fulfill their nutritional needs. Leading to a decrease in weight.

Underweight females are prone to develop oestrus complications, return to oestrus or in worst case will not be able to get inseminated successfully. If the feeding restrictions are severe it is possible that the whole group will be late for oestrus. [4]

Next to the reproductive aspect feeding competition can be a stressor as well. [42] Another stressor factor is the size of the feeding space. If the slot is too narrow the sows will not enter. [58]

Next to good quality ad libitum feeding the water intake is an important factor too. Especially for the appropriate body temperature regulation to prevent heat stress. Sadly water gets underestimated in the farm management which is a big mistake. Inadequate drinking systems, contaminated water (chemicals, toxins, germ load,..) water shortage in general or too few drinking spots for the pigs in the pen – those are the most frequent problems that encounter the breeding sow. Due to microbiological contamination also infectious diseases of the reproductive tract can be the result. [43]

For breeding pigs the minimum demand of water intake is 100ml/kg per day. The table below indicates the needed amount of water per day of the pig throughout it's life:

Table 6: Water demand [25]

Pig	**Water demand (liter/day)**
Piglet	1-2 l (including milk)
Gilt	5-10
Gestation	25-35

If the water requirement is not met, urinary tract diseases can be the consequence which has a direct influence on the reproductive organs and performance. It is beneficial to add 1% NaCl, Ammonium chloride or Methionin to prevent urinary tract complications so the urinary system gets flushed through properly. [44]

3. Housing and grouping management

When it comes to husbandry management many different aspects have to be taken into accountant. Factors like stable size, grouping and regrouping of animals, temperature and hygiene in general are the aspects which will be discussed in the following chapter. [4]

Each stage of the reproductive cycle would need a different housing system. Weaned breeding sows get selected on growth rate, fat composition and performance before placing them into the pen. Only superior gilts should be selected and kept to avoid wastage. After selection the gilts can be housed in groups together to achieve the goal of mutual immunization, experiencing social uniformity to prevent social stress and adapting to the new environment as post weaning is a extremely stressful event for pigs. In order to achieve a social order fights and aggressive behviour can be seen among the gilts. Aggressive behavior already starts after the first hours after grouping and takes approximately about two to seven days until the group becomes socially stable. This actions frequently end up with injuries and later in reproductive complications. As those actions will increase the stress level significantly failure in oestrus expression or failure in maintaining pregnancy are likely to be the consequence. A technique to avoid those consequences keeping the pigs in individual stalls and using artificial insemination. [45]

A study showed that when keeping a larger sized group the observed injuries were less than keeping a small group. [46]

There is a three phase integration system for breeding gilts which will be described below:

Table 7: Grouping of gilts [64] [63] [52]

Integration phase	Adaption phase	Insemination center
2-3 weeks	4-6 weeks	After 6-9 weeks
• Resting phase after stressful relocation • No contact to old sows	• Targeting adaption of gastrointestinal flora of herd	• Inclusion of gilt into planned sowgroup
• Protection of herd from pathogens → vaccination program: - PRRS, Influenza	• Building a strong and stable immunity of gilts • Core immunization	• After reaching 220 days of age or 130 kg: 1st service • Flushing feeding • Steady contact to boar until first heat is detected

- Parvo-Rota		
• Oestrus and heat control • Documentation of heat signs	• Oestrus and heat control • Documentation of heat signs	• All in all out stragety of cleaning

Picture 1: Gilt grouping

Picture 2: Gilt stable

When having a look at the architecture of a stable many different types of pens and stalls are available now.

From the animal welfare point of view the free access stalls can be beneficial. Those kind of stalls are designed to lower the risk of aggressive and fighting behavior. [45] Less fighting and injuries are correlating with a better reproductive performance and gilt development. Moreover they are equipped with a non-competitive feeding management and a social area. The stalls contain gates which can be opened by the sow and automatically closes afterwards which gives the sow freedom as they can enter and leave at any time. Another benefit is that all animals can be fed at once as a group which significantly reduces the risk of feeding competition. [29] If all females are fed at the same time the heat inspection can be done easily when walking past which is the most

important tool in reproduction. Those kind of stables often have electronic sow feeder-system which is able to give tailor made meals for the animals with the goal to perfectly meet their needs depending on their weight, age and on their current stage of oestrus cycle. When electronic feeding systems are used the pigs must be trained and should at least have a size of 1,8 square meters per animal. The better the animals are trained the better the result. [52] Therefore a well educated team at the farm is needed. Next to perfectly sized meals the electronic feeding systems allows the animals to eat in peace and without the risk of getting injured by another animals which is a big plus point in animal welfare and stress management. To conclude the mentioned feeding system is a good tool to achieve maximum sow efficiency, improved sow condition and reduces aggressions in the herd. [47]

The next picture shows farrowing crates. Even tough farrowing crates are still legal in some European countries - from the animal welfare point of view they are not suitable for meeting the sows' welfare standards as they are too small in space and the pig is not able to meet it's needs and express normal behaviour. [65]

Picture 3: Farrowing crate

4. Temperature, Heat stress

The adults pig's body temperature is homeothermic and remains constant at 39°C as the animals can perfectly adapt their core temperature to their surrounding circumstances. [3]

This adaption is regulated by physical movements (posture, crowding) or also throught metabolic heat production. [13] Nevertheless pigs are not able to sweat which makes them super sensitive to thermal changes especially to high temperatures.

The reasons for developing heat stress can be due to climate changes and extreme hot summers and also bad management on farm. Unproper ventilation, lack of clean water or direct exposure to sunlight without shade or cooling places are the main sources of the problem.

The term 'summer infertility' refers hot summer weeks and months where the external temperatures is constantly higher than the internal mechanism can manage and also long photoperiods can be a disadvantage too. [9]

If the body temperature is increased due to exposure to heat over a long period of time heat stress will be the result. An increased breathing pattern, open mouth breathing, constant laying on the floor, tremors and not being able to move can be observed in case of heat stress as the homeothermic mechanism are not working properly anymore. [21] Another important clinical sign is the reduced appetite, reduced feed intake and a drop in reproduction. When facing the internal consequences of heat stress a disturbance in the ovarian functions as it is leading to a higher rates of returning pigs, unsuccessful inseminations and a delay in the onset of puberty. [48]

In some cases sows or gilts even fail to show oestrus behaviour. On the one hand the reason for this negative reproductive events is the stress reaction and therefore hormonal imbalances and on the other hand due to decreased feed uptake the LH production will be on low levels. As already mentioned in previous chapters LH is essentials for the maturation and ovulation of follicles. [49]

The table below shoes strategies on how to prevent heat stress:

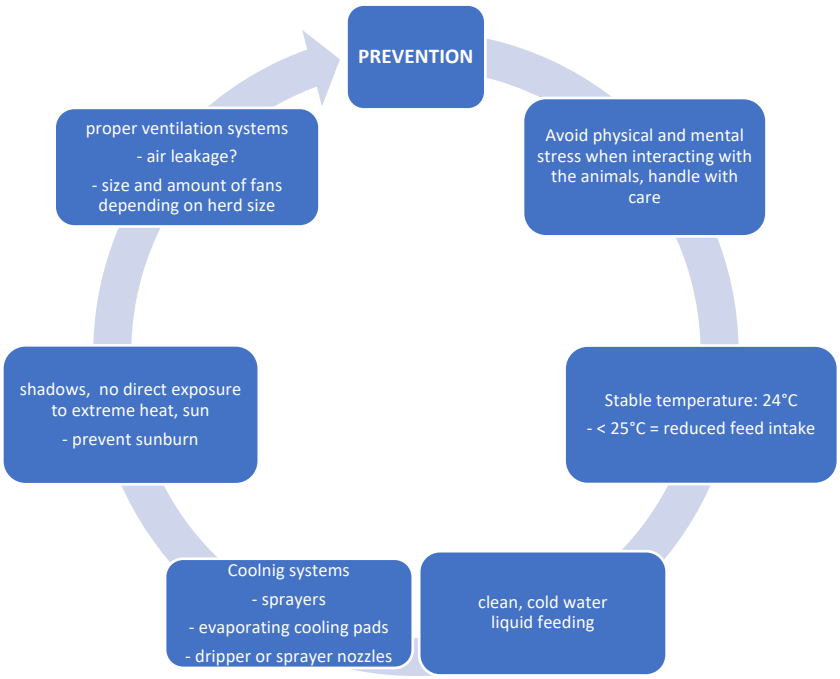

Figure 4: Strategies to prevent heat stress [50] [47]

b. Boar management

As already mentioned in previous chapters the contact with the boar has an essential role in swine production. In this chapter the focus will be on the boar effect.

The so called boar effect is the stimulation of female pigs by the presence of a sexually matured male pig. [51]

Next to the positive effects of using a boar there are also complications that can occur with using a boar in order to improve the reproduction.

If the there are too many gilts or sows in a pen and only a few boars are used for stimulation it makes it really difficult to perform a efficient heat detection among the females. Another factor is the time of exposure of the boar in the pen. [52] For the best outcome as possible the boar should be used only once per day for 15 minutes per day. Rule of thumb is one boar for 20-30 female pigs.

When entering the gilts' pen the boar can enter the pen, experience nose to nose contact while walking down the aisle of the pen or some farm even have a special boar exposure area. This procedure can be done for maximum one week. [14] This strategy might not work for each gilt or sow as each one is individual. It can happen that no signs of heat can be detected even though a boar was presence as the duration of exposure was too short. This can become a managemental challenge.[4]

There are some factors that need to be considered for choosing the right boar. The age and the sexual maturity of the boar is the central factor. Boars younger than six month of age are not mature enough to synthesize the amount of pheromones that are needed by the sow. [25] Three different ways of physical contact can be used: either the full contact where all types of stimuli can be satisfied or the fence line tactic is the second option where only the olfactory, visual and auditory senses are included. The third strategy is the indirect contact where the active boar is placed in a pen in the females' stable. When using the third strategy only the olfactory and auditory stimuli are present. [53] An interesting fact is that even if the boars are at the same age as the sows or gilts they are not able to stimulate them successfully. Another important point is the gilt's age at the first time of stimulation through the boar as it the timing has an influence of the onset of getting into heat for the first time. When comparing younger gilts (approximately 140 days of age) to older gilts (170+ days of age) the younger ones will show milder or even none detectable reactions of oestrus after getting stimulated by the boar. [9] The interval from the start of stimulation to the onset of getting in heat is dependent on the frequency and onset of the stimulation per day. The advised time to get the maximal boar effect of contact between boar and female is twice daily for not longer than 20 minutes

V. Return to heat

The terms 'returning to oestrus' or 'returning to heat' or 'return to service' are synonyms and refer to the condition of a sow if she is not able to maintain pregnancy after insemination and is not able to maintain pregnancy. [9] Clinically it is defined as situation where the sow gets back into heat without experiencing abortion or delivery. Returns are one of the most frequent problems in porcine reproduction and is termed to be an infertility problem. [47]

The range of causative agents of returns is wide and can either be infectious or non-infectious. Apart from the reason the outcome is an economical challenge and an important hint for the keeper to check the management and generally the pigs' health status. [50] The pathogenesis for returns are weak or no ovary functions or pathological changes of the ovaries. An especially common reason is the lacking or insufficient sexual stimulation of the sow by the sexual mature boar. On the other hand influencing factors like nutritional deficiencies in particular Vitamin A, Phosphorus, Calcium, Manganese and proteins or a decreased energy level, too hot temperatures (heat stress), sunburn or overcrowding in the pen are common issues resulting in a return to oestrus. [9] It is very useful to take feedstuff samples on a regular basis and do a toxicological examination to surely exclude contamination with mycotoxins.

When facing the reproductive performance of a stock the farrowing rate should almost always be higher than 85%. If this rate is lower than the chance of returning sows in the herd is high. [9] The range of causative agents of returns is wide and can either be infectious or non-infectious. Apart from the reason the outcome is an economical challenge and an important hint for the keeper to check the management and generally the pigs' health status. [54]
There are two different kinds of returns: regular returns and irregular returns. The detailed categories are presented in the chart below:

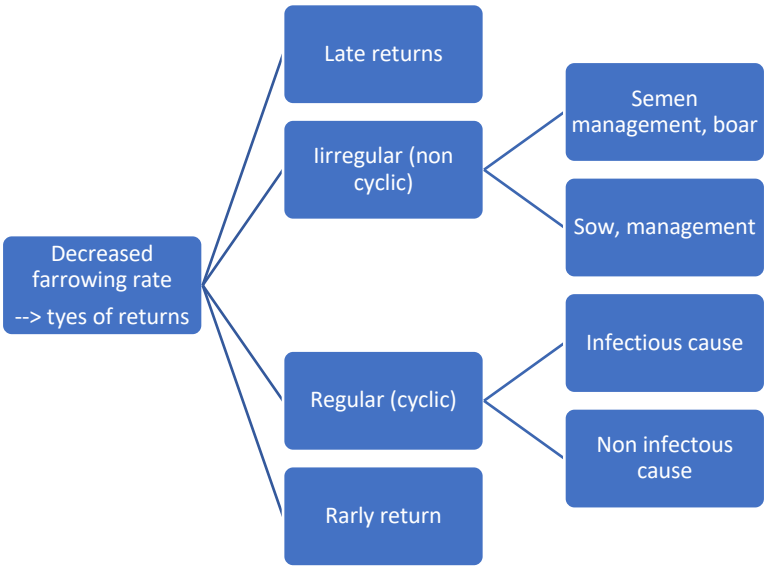

Figure 5: Return to oestrus

a. Regular / cyclic return to oestrus

In this form the return happens somewhen between the 18th and 24th day after breeding. In general female pigs are cycling in a 3 week interval if no fertilization and nidation has taken place. Regular returns can also happen after 10-13 days of pregnancy. In addition if pigs return in intervals between 36-48 days or 54-72 days it is still termed as a regular return. In many times those pigs only show very weak heat signs which makes the detection difficult. [25]

The list of causatives agents behind a regular return is long and diverse. When looking at the farm management, the general housing aspects but also the boar has a huge impact on the sow's health. [50]

Semen quality will be the first aspect as it directly influences the outcome of the insemination. What should be highlighted when it comes to boar semen? The bullet points are summarized below:

Table 8: Semen quality [55] [56]

Management	Macroscopic criteria	Microscopic criteria
• Do not collect the 1st phase semen • 2nd phase: 50 ml, sperm rich fraction → place in pre warmed thermos cup • 3rd phase: 80 ml, decreased level of sperm cells • 4th phase: 200-250 ml,	• 2nd: cream like texture • 3rd phase: grey color • 4th phase: transparent color	• Check with microscope • Use 100x or more magnification • Use a clean slip glass • Motility: forward moving • Sperm morphology: Not more than 25% abnormal appearance • Cytoplasmic droplets: not more than 15%

	• In total 250-400 ml fluid in total • Visual on field inspection for pathological changes (color, texture, smell, consistency)	with proximal and distal droplets • Concentration: more than 15 x 109 sperm cells/ejaculation • Photometric evaluation, counting chamber for flow cytometry for semen quality

For the best result only semen from approved semen collection centers should be used for breeding as the boar's semen is checked for macroscopic and microscopic criteria and can be traced back. When using a checked semen the breeders can be sure only healthy boars were used for semen production. [50] Another influencing factor of the boar is the proper stimulation of the sow which was mentioned in the previous chapter already. After the sterile and clean semen collection at the center via mounting dummy and the gloved hand technique or electroejaculation. The freshly collected and diluted semen must be stored at 14-17°C and the non-diluted semen at 34°C but only for a couple of hours. [57] Next to the quality and correct handling of the semen the artificial insemination is critical point as well. If the person doing the artificial insemination is not skilled enough to successfully fertilize the sow the nidation will not happen and as a consequence the pig will return to oestrus. [55] Moreover the hygiene must be at a very high level when handling with semen and doing the artificial insemination.

Further problems in the farm's management include too high temperatures in the stable or a too long exposure to direct sunlight resulting in heat stress or sunburns.

More specific information about heat stress can be found in the previous chapter. Also lack of ventilation can worsen the situation. [52]

When looking at the site of infectious issues many in cases abnormal vulvar discharge can be observed due to pathological changes in the reproductive tract. [13] The reason for inflammations and dysfunction is due to influencing external factors which have a big impact on the immune system. Management errors will weaken the pig's immune system and lead to an increased chance of inflammations and infections. As the normal function of the organs is despaired the pig is not able to maintain a pregnancy and will return to heat. [9] In infectious cases it is important to improve the external circumstances as well. Medical treatment alone cannot be used for treating a returned pig. Infectious diseases like Porcine Reproductive and Respiratory Syndrome (PRRS-Virus), Leptospirosis or Swine Influenza Virus (SIV). [4] To prevent an outbreak of infectious diseases and in further steps to prevent a return to oestrus the vaccination program should be taken serious. The best outcome can be achieved if piglets get vaccinated around weaning age. [58]
As already mentioned feeding hygiene is another key tool in prevention. Especially mycotoxin intoxications easily cause returns. More information about mycotoxins are found in the second chapter.

b. Irregular / non-cyclic return to oestrus

An irregular return to oestrus is defined as a return in 25-35 days after a successful fertilization of the sow. In this case a nidation of the embryos into the uterine tissue has already happened but got disturbed. [9] In contrast to the regular return – during the irregular one too few embryos got fertilized. For a successful gestation a number of at least five embryos must be fertilized and get attached to the uterine wall. This attachment is the key point of maternal recognition of pregnancy. [59] The embryos die or get resorbed shortly after insemination in irregular returning pigs.

The reasons for the irregular return are quite similar compared to the regular ones. Irregular returns frequently happen due to ovarian cysts and ovarian anomalies. Especially single or a couple of small cysts influence the return-rate of the herd. In general the irregular return rate should not be more than 3%. [9]
Ovarian cysts are located on the ovarian surface and are exclusively from thin walled nature.. They are filled with a clear, transparent, non purulent or viscous fluid.

Their origin are non-ovulated follicles which means they are hormonal dependent. The clinical background of developing cysts is not fully understood yet. Mainly exogenous, managemental factors that increase the stress level in pigs is a common cause. [60] As already mentioned stress will increase the ACTH level and result in a disbalance of LH and FSH. The consequence is a non fully functional ovary which is not able to ovulate and end up with the development of one ore multiple cysts. [61] Moreover the unproper use of hormones or medicated feedstuff in breeding sows can be a start for cyst formations. [60]

VI. Method of evaluation

When I started my literature research I asked my supervisor first. Dr Rátky handed me some journals and articles that helped me to get into the subject. For the first chapters about anatomy and physiology I primarily used my own anatomy and physiology books I bought in 1st semester which was very handy for me. Several books also had a online PDF version what made the research for specific topics easier. Furthermore I started to gather scientific content using online platforms like Google Scholar, Google Books or Scribd. When reading through the papers I quickly noticed that Dr. Robert Knox was mentioned many times who is a swine expert at the University of Illinois.

For some chapters it took a while to find appropriate literature and therefore I asked veterinarians of my area for some scientific publications. Luckily they could help me out and sent me articles and papers regarding the chapters. One of the books I used for my literature review was written and published by the leading veterinarians of swine clinic I did an internship at.

VII. Summary

The essence of this literature review was to show the impact of the sow's well being on the reproductive performance throughout the pig's life. In current times animals often get treated like objects bringing as much profit as possible without caring much about their emotional or physiological status. Pigs need more than just a tray filled with feedstuff. Pigs are extreme sensitive animals and relay on the farmer's practice and expertise. As the literature review shows there are many stressful phases that should be handled with care. Each aspect that influences the reproduction should be selected in regard to achieve a prime result.

The reproductive life of a sow is already starting at the point when the piglet is suckling colostrum for the first time as it hugely determines it's immune system. If the immune system is weak from the beginning of life the pig is extreme sensitive to any environmental changes and prone to get infectious or non-infectious diseases. This is why it is from highest priority to check the farm management continuously and to always be up to date regarding feeding technologies, housing management and hygienic aspects.

While doing internship in the swine medicine sector I often noticed farms are using the systems their grandparents installed there. These are the farms that are then wondering why their success is rather low as they are lacking of knowledge and expertise about the latest regulations or sometimes even do not really understand what breeding pigs really need. That's the point where the veterinarian must interact and educate the keeping person. Furthermore several papers and books from 20th century mention really outdated techniques and way of thinking. Thus it was very interesting to compare the old and the new point of views.

A very interesting point while doing research was how stressful events almost always is part of the game and is quite often the source of an health issue like a return to estrus or a delayed puberty. Several stressors that are mentioned in the review could easily be managed and would be a great benefit for the sow's health.

VIII. Conclusion

The aim of the literature research was to give an insight into the physiology of heat in female pigs and to describe the related clinical complications leading to a reduced reproductive performance. The female reproductive system can be compared to a puzzle as it contains several aspects and each piece of it is needed in order to get a complete picture. It does not matter how small the piece is – it counts. The literature review wants to point out that all factors in management have an impact on the sow's reproductive health and the ability to get into heat.

When facing the physiological aspects of getting into heat the puberty is a critical time period of the young sow. Hormonal changings, change of stable and new social hierarchies are waiting for the animals. If the pig is experiencing too much stress the puberty can easily be delayed and bring many other consequences. The most important consequence the disbalance of the endocrine organ systems and feedback mechanisms. In stress situations the ACTH levels will block the follicular development and no ovulation will take place and in some cases the pig will not be able to get into heat at all. Next to stress the nutritional impact is a big point. Especially during regrouping of gilts maximum stress levels can be measured. In extremely stressed pigs it is often not able to detect external changes in their first heat as it can be missed resulting from stress. Another problem in regrouping is the experience of fear and aggression among the group.

Undernourished animals will also not experience a successful puberty and will miss heat too. A nutrition that is high in energy and trace elements is essential. A common way of providing a general good nutritional basis is the practice of flushing before service where the pigs get bigger amounts of ad libitum feed in order to stimulate FSH and LH. A great problem in feeding management is the contamination of mycotoxins. The toxins act on the immune system and therefore also weaken the reproductive tract leading to a weak ability to express heat.

In cases where the farm management is favorable and the animals get into heat the heat detection is positive. For a reliable heat detection the responsible person must be aware of the physiological and behavioral changes of the sow. To conclude it can be said the prime way of detection is the daily observation of the pigs where the external genitals are checked twice daily and the general behaviors is observed. Even though ultrasonographic devices can be used for heat detection – it still is not common in field practice. Performing

the back pressure test or riding tests is the better and time saving option as they deliver prompt and reliable results. In order to have a good heat the sow needs a sufficient stimulation. Therefore, it is practical to use a sexually mature boar allowing nose to nose contact between boar and sow. If the boar is not mature enough the sow will not be stimulated.

The review also shows the impact of management, semen and animal welfare in the means of experiencing stress and not being able to fulfill the pig's nutritional demands on the reproductive organs' health condition. This means a reduced chance of a successful fertilization due to a return to oestrus for example. A return can be caused by many reasons, the most common are either viral diseases, poor semen quality, stress or ovarian cysts. Farms experiencing too frequent returning pigs should gather professional advice from a veterinarian.

In conclusion it can be stated that the pig's reproductive success is extremely dependent on the environment, keeping and feeding strategies and the usage of a sexual mature boar. All of those aspects refer to a good animal welfare practice and influence the farm's economic outcome too.

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I hereby confirm that I am familiar with the content of the thesis entitled

The physiology and complications of heat in sows.

written by **Ines Maria Pichlmann**

(student name) which I deem suitable for submission and defence.

Date: Budapest, 3 day 11 month 2023 year

Prof. Dr. Rátky József
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Thesis progress report for veterinary students

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The thesis meets the requirements of the Study and Examination Rules of the University and the Guide to Thesis Writing.

I accept the thesis and found suitable to defence,

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Signature of the student: .....

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Date of handing the thesis in ....