GROWTH, BEHAVIOURAL AND REPRODUCTIVE RESPONSES OF PIGS TO WEANING AND INTERMITTENT SUCKLING REGIMES

BY

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DEDICATION

This research work is dedicated to the Almighty God, the Alpha and the Omega, the First and the Last, the Beginning and the End, the immortal, invisible, the only wise God, and to my parents, Mr and Mrs Kehinde Olusegun Bankole.

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ABSTRACT

Early weaning of piglets is gaining attention worldwide. Although, this encourages quick rebreeding of the sow, it subjects piglets to weaning stress. However, intermittent suckling makes weaning less-stressful for piglets but the effect on behaviour and performance of piglets and the sow has not been well documented. Therefore, different weaning and intermittent suckling regimes were assessed on piglet growth, behaviour, stress response and reproductive performance of sows.

Eighteen newly farrowed sows (Large white×Landrace), each with four piglets aged 1-3 days were randomly allotted to different weaning regimes: four weeks (T1), six weeks (T2) and eight weeks (T3) at 6 replicates/treatment, in a completely randomised design. In another study, sixteen newly farrowed sows, each with four piglets aged 1-3 days were randomly allotted to four treatments: S1 (Continuous suckling), S2 (4 hours separation/day), S3 (8 hours separation/day) and S4 (12 hours separation/day) at 4 replicates/treatment, during the last two weeks of the six weeks suckling period. The sow and piglets were evaluated at pre-weaning and post-weaning phases for weight-change (kg), Feed-intake (kg), Feed Conversion Ratio (FCR), stress (serum corticosterone level [ng/mL] assayed for two weeks using standard procedure), behaviour (feeding and aggression (%) which were monitored from 08:00-12:00 hours for 10 days using CCTV). The sows' reproductive indices (weaning-to-oestrus interval (days) and conception rate (%) were monitored. Data were analysed using descriptive statistics and ANOVA at $\alpha_{0.05.}$

Weight-loss in sows in T2 (-6.25±0.33) and T1 (-5.00±1.41) were significantly lower than T3 (-10.00±1.58). The FCR of weaners in T2 (2.23±0.15) and T3 (2.22±0.10) were significantly lower than T1 (2.42±0.09). Corticosterone of weaners in T2 and T3 on day 4 (48.60±3.90 and 48.31±3.95) and day 7 (46.45±6.67and 46.96±2.36) were significantly lower than T1 (55.83±5.28 and 54.25±1.66), respectively**.** Feeding behaviour ranged from 41.7 (T1) to 70.3% (T3), while aggressive behaviour ranged from 0.5 (T3) to 9.2% (T1). Weaning-to-oestrus interval in sows at 7.00±1.22 (T2) and 6.00±0.71 (T1) were significantly lower than 10.00±1.58 (T3), while percentage conception ranged from 83.3 (T3) to 100.0% (T1). Piglets in S1 had significantly lower feed-intake and higher weight-gain (0.90±0.15 and 4.86±0.30) compared to S3 (2.20±0.33 and 4.17±0.15) and S4 (2.50±0.31 and 4.14±0.19), respectively. The FCR of weaners in S3 (2.83±0.16), S2 (2.87±0.22), and S4 (2.84±0.20) were significantly lower than S1 (2.99±0.26). Weight loss in sows significantly varied from -3.21±0.60 (S4) to -5.07±0.70 (S1). Corticosterone of piglets in S4 (59.43±0.66) was significantly higher than S3 (57.74±0.67), S2 (57.44±0.65) and S1 (43.86±0.76) on day 4, while corticosterone of weaners in S3 (47.02±1.47), S2 (50.16±1.53) and S4 (45.08±0.84) were significantly lower than S1 (54.66±2.08) on day 4**.** Feeding behaviour of weaners ranged from 8.2 (S1) to 51.5% (S4), while aggressive behaviour ranged from 0.0 (S4) to 11.8% (S1). Weaning-to-oestrus interval in sows in S3 (4.00±0.71) and S4 (4.00±0.00) were significantly lower than S1 (7.00±1.00) and S2 (6.00±0.71).

Weaning at six weeks, with 8-hour daily separation in the last 14 days, improved piglets' post-weaning growth and sows' weaning-to-oestrus interval. It also reduced aggression and stress in weaned pigs.

Keywords: Maternal separation, Weaning stress, Pig aggression, Intermittent suckling

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Conventionally, piglets are separated from their mother and transitioned to solid food between the ages of 3 to 4 weeks (Kuller *et al*., 2004). However, late weaning results in prolonged lactation, excessive weight loss and thus lengthen the time for their dam to attain optimal body condition for rebreeding (Diana *et al*., 2016).

Although weaning piglets early has benefits for production and the economics, a shorter lactation period means that most piglets would have consumed minimal or negligible amounts of solid feed before being weaned (Boudry *et al*., 2004a). The ability of piglets to develop their immune systems independently, without relying on maternal antibodies, determines their readiness for weaning.

Weaning as early as 3–4 weeks has the added advantage of allowing the sow to mate more quickly and produce more piglets per sow per year (Brooks and Tsourgiannis, 2003; dos Santos *et al*., 2004). However, weaning piglets earlier than 5 weeks results into reduced intake of feed and weight gain post-weaning and this may eventually affect their growth rate throughout the growing phase (Brooks and Tsourgiannis, 2003).

Weaning is stressful to pigs as it has effect on the well-being and growth of the animal, particularly in the initial week post-weaning (Pluske 2013; Yin *et al*., 2013). Commercial systems experience modifications to the social and physical surroundings more frequently than outdoor systems do, and this can cause noticeable behavioural and physiological reactions during weaning (Weary *et al*., 2008). The post-weaning growth-check, which refers to the common phenomenon of piglets experiencing a temporary halt in growth or even weight loss within the initial one to three days after weaning, is a regular and expected event. Piglets engage negatively with their new pen mates as a result of their behavioural responses to abrupt weaning, and negative behaviours like belly nosing are frequently seen (Dybkjaer, 1992). Negative behavioural habits, such as chewing on other pigs' tails or ears, may result from maladaptation (Blackshaw, 1981).

Intermittent suckling, a weaning strategy to reduce weaning stress which involves a short-term daily separation of piglets from their dam towards the end of lactation before weaning, has been hypothesised to make early weaning a stress-free event for piglets (Weary *et al.*, 2002). It is a steady weaning process that imitates the increasing hours a sow spends away from its piglets in the wild.

Intermittent suckling increases intake of solid feed by piglets pre-weaning and a subsequent enhancement in their growth post-weaning. This is because piglets are forced to explore and become more familiar with other source of nutrient (creep feed) when they do not have access to suckling milk during the period of separation. It also eliminates physiological and behavioural changes indicative of compromised welfare after weaning (Berkeveld *et al.,* 2009). Piglets exhibit better performance after weaning when subjected to intermittent suckling not only because they are used to eating creep feed before weaning, but also because they are used to maternal separation (Kuller *et al*., 2004). Diana *et al.* (2016) noted that piglets that were subjected to intermittent suckling showed no physiological or behavioural changes that suggested impaired welfare. Intermittent suckling has been reported to reduce weight loss in sows during lactation as well as weaning to oestrus interval (Kuller *et al*., 2004). Reproductive performance of the sow is affected by its metabolic state (Foxcroft, 1992). Vesseur *et al*. (1994) noted that the time between weaning and the onset of oestrus was extended when sows experienced weight loss exceeding 12.5%. Sows are often catabolic and lose weight during lactation because their feed intake is often not always enough to satisfy their nutrient requirement for production of milk. Therefore, the sow mobilises the tissue reserves thereby losing weight. However, the period of separation reduces suckling by the piglets which leads to reduction in milk production, weight loss and the interval between weaning and oestrus (Kuller *et al*., 2004).

This study therefore investigated the effects of different weaning time, and increasing hours of separation of piglets from their dam on growth, behavioural and stress responses of the piglets. Also, the effect of different weaning time, and increasing hours of separation of piglets from their dam on the subsequent reproductive performance of the dam were assessed.

1.2 Statement of Problem

Weaning process subjects the weanling pigs to a period of weaning stress which results into reduction in feed intake and weight gain immediately after weaning. However, weaning time determines the severity of weaning stress on the weanling pigs (Kuller *et al*., 2004). Therefore, there is a need to determine the optimum weaning time.

Intermittent suckling has been reported to make weaning a stress-free event for weanling pigs. However, there is a need to determine the optimum duration of separation of piglets from their dam that is required for better performance of the piglets and the dam.

Prolonged lactation period causes excessive weight loss in the dam and thus lengthens the time for the dam to attain optimal body condition for rebreeding.

1.3 General Objective

Improvement on the productive capability of pigs through weaning strategy.

1.4 Specific Objectives

- To assess the effect of different weaning time on weanling pigs' growth, behaviour, stress response and subsequent reproductive performance of the dam;
- To investigate the effect of durations of intermittent suckling on piglets' growth, behaviour, stress response and subsequent reproductive performance of the dam; and
- To evaluate the effect of durations of intermittent suckling on weanling pigs' growth, behaviour, stress response and subsequent reproductive performance of the dam.

1.5 Hypothesis Tested

H_0**:** Weaning time has no significant effect on weanling pigs' growth, behaviour, stress response and subsequent reproductive performance of the dam

H_1: Weaning time has significant effect on weanling pigs' growth, behaviour, stress response and subsequent reproductive performance of the dam

H_0**:** Duration of intermittent suckling does not have significant effect on piglets' growth, behaviour, stress response and subsequent reproductive performance of the dam

H_1**:** Duration of intermittent suckling has significant effect on piglets' growth, behaviour, stress response and subsequent reproductive performance of the dam

H_0**:** Duration of intermittent suckling does not have significant effect on weanling pigs' growth, behaviour, stress response and subsequent reproductive performance of the dam

H_1**:** Duration of intermittent suckling has significant effect on weanling pigs' growth, behaviour, stress response and subsequent reproductive performance of the dam

CHAPTER TWO

LITERATURE REVIEW

2.1 History and Classification of Domestic Pig (Swine)

The domestic pig (*Sus scrofa domesticus* Erxleben) is also known as hog, pig or swine when differentiating it from other kind of pigs; it is even-toed but ungulate. They are considered a sub-species of undomesticated boar, or a special species (Lockhart, 2015). The pigs are forest-dweller from its history but have been domesticated for about 10,000 years in some part of the globe with several sites of domestication recognised across Europe and the Near East (Larson *et al.,* 2005). The distribution of pigs throughout the world is not uniform. In the findings of Holness (1991), pigs are discovered in the tropical and temperate regions where no religious edicts prevent it from being reared. In the same study, it was also observed that pigs are fast growing animals with the potential of achieving more than a hundred-fold increase body weight before 12 months of age, and the output of meat per tonne of live-weight of breeding female per year is about six times that of cattle. Hence, for pigs to achieve this rapid weight increase and high turnover, large quantities of nutrients are needed for tissue development and reproduction. The domesticated pigs are omnivore as a resemblance to its untamed relative unlike the rest of even-toed, large ungulates which are herbivorous. The aims of rearing domestic pigs are for their hide, bone, and bristles used for commercial products; while miniature breeds are raised as pet, but most importantly, for their meat called pork, which is widely consumed (Anthea *et al.*, 2004).

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Artiodactyla

Family: Suidae

Genus: Sus

Species: *S. scrofa*

Subspecies: ***S. s. domesticus***

Trinomial name: ***Sus scrofa domesticus*** Erxleben (Colin, 1995)

The domestic pig breeds in Europe were obtained from the wild species of pig, *Sus scrofa* whereas pigs from the far East were descendants of wild pig, *Sus vittatus,* which were of higher reproductive potential but smaller in size with shorter legs. The two species interbred easily. However, some wild types of pig-like animals, such as the *Pontamochoerus larvatus* (African bush pig) and the *Phacochoerus aethiopecus* (wart hog), have under no circumstances been domesticated (Anthea *et al.*, 2004).

Pigs in North America were introduced by many of the earlier settlers and adventurers, but the production of pork started thrive in the USA after the establishment of finishing pigs on corn was approved in 1600s (McGlone and Pond, 2003). The implementation of this led to a success whereby, by 1847, the pig population in the USA exceeded the human population twofold, with 35 million pigs compared to 20 million people. Additionally, Cincinnati emerged as the largest global hub for pork trading during that time (USDA, 1981). However, since years after 1850, especially between 1890 and recently, the pig population in the USA has stayed in-between 60 and 50 million. The present breeds of pig originated from diverse crossings between the two original breeds. They create a rich variety of genetic material and over 200 breeds have been documented (FAO, 2021).

Because there isn't enough archaeological or genetic data to form reliable theories about how, when, and where African pig breeds originated, their origins are unknown. While African pig breeds have consistently been neglected, making it challenging to evaluate their existing allelic diversity and establish their genetic connections with other pig populations in the Old World. In contrast, European and Far Eastern pig breeds have undergone extensive studies utilizing diverse marker types (Amills *et al*., 2010). To address this disparity, Ramirez *et al*. (2009) performed the initial genetic assessment of several breeds of pig distributed throughout Eastern (Kenya and Zimbabwe) and Western (Nigeria and Benin) sub-Saharan Africa. Their findings showed no apparent connection between African pigs and Near Eastern wild boars, aligning closely with earlier studies that compared present-day European and Near Eastern *S. scrofa* populations (Larson *et al*., 2005).

The domesticated swine characteristically has a huge head, with an extended snout which is supported by disk of cartilage at the end and a unique pre-nasal bone. Pigs' snout which is a very sensitive organ is strong enough to break up earth in search of feed. The dentition of adult pigs is 3.1.4.3/3.1.4.3, summing up to forty-four teeth. Each foot possesses four hoofed toes, but most of the weight is bore by the two bigger central toes, although the two outer toes are useful for mobility in soft grounds (Lockhart, 2015). The length of pigs' head to body varies between 35 and 71 inches (0.9 to 1.8 m) and adult weight ranges between 50 and 350 kg. The covering of the skin of most domestic pigs contains bristle sparse hairs, although species like Mangalitsa which are wolly-coated exist. They also have the eccrine and apocrine sweat glands, though the former is little at the dorsonasal areas and snout (Sumena *et al.*, 2010). Like the rest of "hairless" mammals such as elephants and mole rat, pigs do not use sweat glands for cooling. Characteristically, heat dissipation by panting from the wet mucous tissue layers of the mouth is not an attribute of pigs like other mammals. The heat safe zone for pigs is between 16 to 22°C. When the temperature is high, pigs tend to combat this through wallowing in water or mud for evaporative cooling, and wallowing has been found to perform other functions which include scent-marking, ecto-parasite control and protection from sunburn (Bracke, 2011). The small lungs when compared to their body size, made domestic pigs to predisposed to pneumonia and fatal bronchitis than the rest of domestic animals. It is because of the flexible nature and omnivorous behaviour of wild pigs that made the early man to easily domesticate it. It has been observed that at any time, the population of pigs alive is about 1 billion, making it the most populous large non-human mammals on earth.

2.2 Economic Importance of Pig Production

The increase in demand for meat of fast growing animals with high feed conversion ability such as swine worldwide may likely cause a rise in growth of the livestock sector (FAO, 2014). Increase in the population of pigs is sparsely distributed around the world with numbers of pigs in Europe and North America continues to rise steadily whereas Asia leads the increase. In Africa, where "farm animals" has literally been considered to be “ruminants”, increased adoptions of pig husbandry have recently led to rapid growth in pig’s number. Some factor has been found to affect pig production size of any given region, these includes; social, religious beliefs and climates, there were fewer pigs in countries dominated by Muslims.

Pigs are one of the most fast growing and highly prolific farm animals which have the ability to convert feed waste to meat (Osaro, 1995). Hence many Nigerian farmers have ventured into intensive pig production in an effort to increase the supply of animal protein, at a cheaper price for human use (Adesehinwa *et al.*, 1998). Production of pig presents a more efficient way of alleviating animal protein scarcity of Nigeria, Africa and world at large. The report of WHO (2015) reveals that due to economic situations in general, an average Nigerian lives below $1 per day, making animal protein happen to be luxury rather a dietary need because only a certain class of population can conveniently afford it. The deficiency of protein in diet results in anaemia, fatigue, weight loss and poor appetite in adults and in children produces diseases such as kwashiorkor and miasma.

Rearing of pigs have some distinctive advantages above all other livestock, among these are their meat quality, which is tender and of a more nutritious quality in its contents of B - Vitamins and protein, their high potential of large litter which is incomparable to any of other livestock breeds with the exception of poultry, their excellent feed conversion ratio which brings superior returns per unit inputs than most other livestock, their rapid growth rate that is merely surpassed by the most excellently handled broilers, and above all, pigs exhibit high prolificacy, which means they have the capacity to produce two or more litters within a single year. In numerous societies across the developing world, indigenous pigs are the preferred choice of monogastric mammals for rural families to enhance their protein intake and augment family income because of their feed requirements and less intensive management. There is also a more rapid return rate on investment in comparison with cattle i.e., good weight gain, fast growing, and short gestation interval (Osaro, 1995). They can be raised to market weight of 90kg when fed for 6-7 months under average feeding and management conditions in a humid tropical climate. Pigs have high feed conversion ratio, converting concentrated feed into meat twice as efficiently as ruminants. Dressing pig’s carcasses are easier which have superior curing qualities that are responsible for its higher shelf-life compared to other meat; these are easily distributed across a wide range of populace. Pig industry creates employment opportunities for the people, and by so doing, providing a source of income to the populace. One additional benefit of this sector is that the feed materials frequently consist of industrial waste, readily accessible at a low cost. Pigs are generally efficient species in converting non-conventional feedstuffs and kitchen wastes into flesh (Adesehinwa, 2008).

Agada (1991) made known that the slow growth or neglect of the pig industry can be ascribed to the problems which include all management problems and religion acceptability. These include problem of high cost of feedstuffs, feed efficiency and disease outbreak, which is as a result of being deficient in skill, knowledge of swine production and habitually the Nigerian farmer unaware of new techniques and ideas to perk up production.

2.3 Pig Management

2.3.1 Management of Weanling Pigs

The practice of separating the piglets from the sow in order to feed on their own is called weaning. This is accomplished by removing gradually the sows from the farrowing sty leaving just the piglets. Pre-weaning diet is required to include at least 20% of crude protein from ingredients with an excellent balance of amino acids such as fish meal and milk (John, 2007). When piglets are weaned, proper care should be given in terms of continuous creep feeding, freshwater, optimum temperature and conducive environmental conditions for at least two weeks after weaning (Holness, 2007). The weaning process for piglets is linked to social stress caused by mixing piglets from other litters, environmental stress, psychological trauma of separation from their mother, loss of antibodies which provide immune protection from the sow's milk and nutritional stress (Serres, 1999).

An alternative approach is split weaning, where the heavier piglets are separated from the sow and weaned first, while the lighter ones are left to continue nursing. This allows the lighter ones to have added weight and weaned later to enhance survival post-weaning (Williams, 2004).

2.3.2 Management of Growing and Finishing Pigs

Growing and finishing pigs are the pigs found between weaning and slaughter (Holness, 2007). Around eight to nine weeks of age, the growing pigs have surpassed the critical phase of encountering various stresses and have also developed a digestive system capable of consuming a variety of feeds (Serres, 1999). In large piggeries, some of the growers are separated into a group called porkers, these are slaughtered at live-weight of about 65kg, baconers are slaughtered at the live-weight of about 70 to 90kg and heavy hogs are slaughtered at live- weight of about 90 to 140kg (Honeyman and Weber, 1996). At times, pigs may be separated into heavy weights and light weights or by sex into females and males in different sty, but usually there is no separation in small scale pig farming. According to Holness (2007), 80% of the feeds used in production of pig are consumed at the growing phase; it is during this phase that the efficiency of feed consumption affects profitability of pig farms. Feeding troughs and other equipment used in feeding the growing pigs should be in good state and suitable to lessen or circumvent feed wastage through contamination and soiling with dung and urine (Sharma *et al*., 1997). Combining restricted and *ad libitum* feeding at various stages of growth may be adopted as feeding system to produce the expected desirable outcome (Williams, 2004). For example, pigs in the growth stage can be provided with unrestricted feeding until they reach approximately 50kg in weight, after which feeding is restricted until they are ready for slaughter. Moreover, it is essential for pig farmers to maintain a high standard of hygiene and on-farm bio-security. Additionally, the implementation of efficient veterinary services is crucial in order to significantly minimize parasite infestation and the occurrence of diseases among growing pigs. Cannibalism, fighting, tail biting, bone fractures, bruises and ear biting can predispose the pigs to other infections and possibly death (Serres, 1999; Holness, 2007). Ultimately, if the health conditions of growing pigs are not well managed, low profitability and productivity of the pig enterprise is inevitable. The incidence of such challenges can be effectively managed via appropriate partitioning of pigs into groups, provision of proper ventilation, bedding, adequate space and inclusion of required quantity of salt to feeds (Honeyman and Weber, 1996) because pigs like other livestock animals require suitable housing condition for improved productive efficiency and optimum performance. Determining the choice of housing for pigs usually centered on comfort and the principle of pig productivity (Holness, 2007), the highly productive pigs are most likely confined in a thermally neutral environment. This is point where the temperature of the environment of the pigs is constantly between the Upper Critical Temperature (UCT) and Lower Critical Temperature (LCT) for pigs. This is when production of heat for metabolic activities is least and pigs is not either reducing feed intake to keep cool nor using feed energy to keep warm (Holness, 2007).

2.4 Weaning

2.4.1 The Natural Weaning Process

Pajor *et al*. (1999) defines natural weaning as a gradual reduction in the interaction between the mother and her offspring, typically accompanied by fewer instances of nursing, lower milk production, and an increased intake of solid food by the offspring. In semi-natural conditions, sows generally nurse their piglets for around 12-16 weeks (Newberry and Woodgus, 1985). During the first week after birth, piglets engage in sucking up to 30 times per day. However, as time progresses, approximately day 10 post-farrowing, the sow progressively spends more time away from its piglets, leading to a gradual decline in the frequency of nursing (Jensen and Recen, 1989). The reduced frequency of nursing prompts piglets to actively search for other sources of nourishment, leading to an elevated intake of solid feed as they explore different feed options. As piglets grow, their energy demands cannot be adequately met solely through milk, compelling them to find supplementary nutrients from solid feed (Boe, 1991; Cox and Cooper, 2001). The gradual decrease in suckling frequency is advantageous for piglets as it promotes their independence from the sow, potentially mitigating the negative consequences of a separation response during weaning. Furthermore, the decrease in dependency can also be advantageous for sows. With the energy that would have been dedicated to milk production now available, the sows can improve on their body condition in preparation for future breeding (Weary *et al*., 2008).

2.4.2 The Conventional Weaning Process

In traditional pig farming, the duration of lactation is significantly shorter compared to what is observed in natural environments. The practice of weaning piglets at the age of three to four weeks was recognised in the 1970s as the ideal age for attaining a financially favorable result (Nielsen *et al*., 1979).

The age at which piglets can establish their independent immune systems, no longer relying on maternal antibodies, is a determining factor for the weaning age. A shorter lactation period offers additional advantages, as it allows the sow to be bred earlier, resulting in a higher piglets produced per sow annually (dos Santos *et al*., 2004). Conversely, extended lactation periods surpassing four weeks within the farrowing crates have welfare consequences for the sow, as it remains restricted throughout the entire lactation period. Determining the appropriate timing for weaning is a highly debated topic in the industry, as considerations of economics, health and welfare often intersect significantly. While early weaning of piglets offers production and economic benefits, it also means that the majority of piglets have had limited exposure to solid feed pre-weaning (Boudry *et al*., 2004b). Unlike natural weaning, sudden weaning in commercial systems, which involve notable changes in social and physical environments, leads to increased stress for both the sow and piglet. This transition can trigger noticeable behavioural and physiological responses during the process of weaning (Weary *et al*., 2008). Piglets typically undergo a temporary growth decline, and in some cases, even experience weight loss, during the one to three days post-weaning. This occurrence is typically known as the post-weaning growth check.

2.5 Pig Behaviour

Generally, the behavioural characteristics of pigs appear to be transitional between that of carnivores and other artiodactyls (Clutton-Brock, 1987). The domestication of pig caused its adaption from a free-range, pugnacious, foraging beast to a more docile animal that can easily be managed in large groups under confinement. The rapid rates of adaptation of wild pigs to rearing in confinement have emphasised the behavioural plasticity of swine.

The behavioural knowledge of swine has been gathered from various research data on physiology, nutrition, breeding and management; however, recently experimental researches in the areas of adaptation, sexual, social, maternal behaviours and learning, have been done making pigs among other domestic mammals the best known species, from the view of behaviour. Domestic pigs seek out to be in group of others, and regularly crowd together to keep physical contact, although they hardly maintain a large herd. However, they characteristically live in cluster of around eight or ten sows, single males and a number of young individuals (Algers *et al.*, 2007).

Resulting from their relatively absence of sweat glands, pigs frequently manage their body heat with behavioural thermo-regulation example of which is wallowing; this in their natural habitat consists of covering the body with mud (Bracke, 2011). However, the duration and depth of wallowing depend upon temperature of the environment. Characteristically, mature pigs start wallowing, covering themselves from head to toe in mud when the environmental temperature is about 17-21°C. Mud can also be used by pigs as a means of protection against parasites or as a sunscreen (Bracke, 2011). Bristled species of pigs drop most of the more-coarse hard hair and longer once yearly, typically in early summer or spring, in getting ready for the warmer months coming.

In suitable situations, pigs in confinement feed incessantly over several hours before sleeping for several others, in disparity to ruminants that normally feed for short period of time, and afterwards rest for a little time. Naturally, swine are omnivores which are vastly adaptable in their eating behaviour and as a foraging animal, they principally consume stems, leaves, roots, flowers, and fruits (Kongsted *et al.*, 2013).

2.5.1 Normal Behavioural Pattern of Pigs

These pertain to the behaviours noticed in pigs when kept in natural conditions, promoting biological functions, which includes reproduction and survival (Lidfors *et al.*, 2005). The natural environment of pigs differs greatly from the rearing environment provided for commercial production; the full ranges of behaviour pigs display in their natural environment are not fully expressed in confinement. For instance, swine in their natural environment spent about 35 to 55 percent of available time foraging feed (Andresen and Ingrid, 1999), while confined animals enjoyed readily available feed with no need to forage.

2.5.1.1 The Exploratory Behaviour of Pigs

Exploration describes the biologically essential behaviours which help in acquiring information on the resources available and immediate environment. In spite of the fact that shelter, feed, water and other required materials are provided, animals in confinement may still have an innate desire to exhibit exploratory behaviours, this is usually observed in intensive pig production, despite the fact that feeds are offered *ad libitum*, pigs still show high motivation to explore, although they are acquainted with their pen-mates and pen (Studnitz *et al*., 2007). The exploratory behaviour of pigs is highly developed involving the use of snout and mouth, this have helped in creating foraging strategies (Arey, 1993). Therefore, the motivation is said to be the needed for exploration. The provision of less quality substrates and the need of foraging substrates might root problems owning to re-direction of manipulative and foraging activities in the direction of the pen components and the pen-mate bodies and this re-direction of behaviour might result in destructive activities like the tail- and ear-biting, aggression (EFSA, 2005, Oluyemi *et al*., 2021) which, could result in stern pain and lesion.

Generally, pigs' motivation in the direction of materials provided can be sustained if the material offered is destructible, complex, manipulable, changeable and includes sparingly distributed chewable parts (Studnitz *et al*, 2007). Largely exploratory behaviours are stimulated by substrates that are likely to avert redirection of the behaviour in the direction of pen mates. The ability to explore helps the pig to be aware of available resources; this is one of the important strategies for survivability when available feed sources are seasonal and exhaustible. Thus, exploratory behaviour includes the foraging ability and appetitive need, which makes the pig to search for, finds and ingest feed (Studnitz *et al.,* 2007). Although pigs have been confined and provided for by humans for numerous generations, they have the capability to use their foraging behaviour in any prevailing circumstances.

Pigs generally explore their environment by biting, sniffing, chewing, and rooting a variety of feed substances which includes items that are not easily digestible. This helps in becoming more acquainted with their environments and the numerous resources available (Studnitz *et al*, 2007). Whenever pig explores its environs, it is with the distinctive intention of detecting an appropriate resting or lying place and feed (appetitive behaviour, also termed extrinsic exploration), likewise to collect wide-ranging information of its environment (intrinsic exploration). Environmental enrichment have been found to perk up the welfare of animal by producing behavioural changes which permits animals to have power over its surroundings by expressing important behaviours such as exploring and foraging (Van de Weerd *et al.*, 2006), however, this can cause irregularities in the pigs' behaviour and physiology for instance, stereotypies (Broom, 1991) and destructive behaviours targeted towards the pen-mates and pen components (Van deWeerd *et al.*, 2005), when appropriate stimulus to express such behaviour is not available.

Curiosity may also be a motivation of the exploratory behaviour of pigs; this can arise as a result of discovering unusual object or novelty searching by the pig. In confinement, when the sty is likely unchanging and barren, exploratory behaviour elicited by pigs is most times a reflection of pigs' keen search for novelty.

Describing the information on pigs exploring ability, Inglis *et al.* (2001) reveals that pigs continues to acquire more knowledge of their environment until a different stimulus becomes adequately strong enough (tiredness, hunger) in overriding the exploring desire. This is an indication of continued pigs' exploration and information gathering in as much as there is no other more prominent motivation of exploring and there is adequate energy to perform it.

2.5.1.2 Rooting Behaviour

One of the natural behaviour of pigs is rooting in which the pig prod something with its snout. Rooting is very comforting, this occurred first after parturition when the piglets is in search of the sows' milk, and this can develop into an obsessive, normal behaviour which is a characteristic of early weaning. Habitually, rooting and digging the soil in search of feed is the character of pigs and this an important behavioural characteristic of pigs. For instance, granting indoor pigs' opportunity with soil (Day *et al.*, 1995) or removing the nose-ring of outdoor sows, immediately they start to root (Studnitz *et al.*, 2003). Likewise, keeping gilts for a period of time with no provision of rooting resources, they root more when they have access to sty with sphagnum (Studnitz and Jensen, 2002). Many researches using pigs implies that there is increased incidence of rooting activities when restricted feeding is employed (Beattie and O'Connell, 2002; Stern and Andresen, 2003), this suggested that if restricted feeding will be used during fattening of growing pigs, increased desire for exploratory activities is likely to occur.

Conclusively, rooting level has been indicated to be associated with the degree of hunger as observed with sows in confinement (Edwards *et al.,* 1993). In addition, strong rooting behaviour has been stimulated by earthworms of an outsized population among village pigs. Also, desire for rooting earth rich in nutrient by wild boar was observed in the findings of Welander (2000).

2.5.1.3 Reproductive Behaviour

A number of sows appear to be extra attractive to boars than the rest and seldom some sows tend to avoid or reject to allow a particular boar to mount. More so, raising females away from the males can cause a delay in the mounting process as the female may not stand for the male when introduced (Soede and Schouten, 1991), although, early puberty can be stimulated in gilts by the presence of boars odour even when other stimuli were not present (Hemsworth *et al.*, 1988). Likewise, the social environment in which a boar is raised has been found to affect its sexual behaviour, increased conception result was observed with boars that shows courting behavioural activities involving nosing of the sow's flanks prior to mounting. In the wild, the sow or in-gilt will build nest for about six hours prior to parturition. The female excavates the ground and covered it using grasses, sticks, straws or some other obtainable substances or objects, the appropriate position for nest making is a well-drained soil capable of providing protection against rain, sun and wind. This characteristic nest building activities is done in order to make available comfort, thermoregulation and shelter for the piglets, nesting will grant protection from predators and harsh weather, though keeping the offspring near the sow and far from others in the herd. This guarantee that the piglets are not trampled upon, and there will not be any cross fostering among the sows (Wischner *et al.*, 2009). Although, farrowing crates in modern pig housing thwart the inherent nest building behaviour of sows, but with numerous materials and stimulus available, sows will habitually show the ability to perform such activities as like those provided with materials for nesting. In the wild, at around six days of age, the piglet's starts moving around with the sows (Stangel and Jensen, 1991) and without external intervention, at around 17 weeks old weaning would have taken place which could start as early as at four weeks of age.

2.5.1.4 Social Organisation

The social organisation in pig production is of matricentric with females dominating while males are temporarily a part of the herd and rather live singly or be in a small group. In confinement, associating or living with the littermates may be throughout pigs' life or be in group of similar or strange pigs of the same size and age. Habitually, lighter weight piglet litters have the tendency to be produced by sows of subordinate social rank, while dominant pigs tend to farrow heavier and male piglets (Mendl *et al.*, 1995). Social organisation is of two types in intensive pig rearing:

2.5.1.4.1 Teat Position

Realising individual positions on the udder following farrowing in piglets happens in the first few hours to about second week, piglets preferably affix themselves to frontal instead of posterior teats. In pigs, stimulation from piglets is required by the sows for milk let-down and stimulating the anterior teats seems to be essential in inducing milk let-down, therefore it is of the benefit of the whole litter to have the teats taken by strong piglets. Sensory inputs such as hair patterns of the sow, birth fluids, vocalisation and odours from mammary gland are predominantly essential immediately after birth to assist in locating the teat by the piglets (Rohde and Gonyou, 1991). Largely, occurrence of fight in young piglets is around the udder and many of which are won at the nursing spot rather than other areas.

2.5.1.4.2 Dominance Hierarchy

This form of social organisation could show up in a group of newly weaned pigs or among unfamiliar pigs recently mixed together. These animals usually fight to create a dominance hierarchy, this behaviour is usually by the use of the snout towards the neck with strong thrusts to the sides. Dominant piglets tend to have increased growth rates than the subdued due to the ability to get attached to the anterior teats; these produces the most of milk with little or no occurrence of mastitis, given the dominance to be kept (Dyck *et al.*, 1987). Hierarchy formation can occur within 24 hours of putting together but the degree of hostility drops drastically after around 60 minutes. Dominance hierarchy is significant as this influences growth, impact productivity and act as the group stabilizer, however under critical circumstances, animals low on the hierarchy might be deprived of water and feed. Pigs mostly identify each other by smell and sight. If a top ranking pig was separated from the litter for around 25 days and the social group remain stable, on return will still maintain its position (Otten *et al.*, 1997). Pigs at the base of the hierarchy are attacked and dealt with as strangers when brought back after few days. Having a stable social rank in pig production is an approach to lessen conflicts in the group; this can be achieved by using all-in, all-out method in which member of the same litter remains unchanged from birth to cull-out. Putting together of pigs of similar weights rather than different weights may boost the growth rate, consequently, reducing the hierarchical differences (Francis *et al.*, 1996). Methods like odour masking which involves using the same odour on all pigs by the use of artificial compounds and/or pheromones, had been found to have little or no consequence in preventing violence and hierarchical instability. This leads to depressed immune system causing an increased susceptibility of the herd to diseases.

2.5.2 Abnormal Behaviours of Pigs

The use of the word abnormal behaviour for domesticated animals perpetually brings up issues about what is normal, especially when the majority of behavioural contrast among wild and domestic animals seem, by all account, to be quantitative instead of qualitative in nature (Price, 2003).

As an important part of animal behaviour, abnormal behaviour is generally referred to as the behaviour characteristically typical of the species, not of the normal behavioural patterns observed in the natural environment of the species or in the range of behaviour exhibited by the species in a non-captive situation (Keeling and Jensen, 2009). To be distinguished from normal behaviours, abnormal behaviours simply means behaviours not evident in the species when observed in its natural habitat. Under confinement therefore, abnormal behaviours is a pointer to poor welfare. In various instances, abnormal behaviours affect the health of pigs or their production performance. It is of anticipation that welfare of animal is at menace if stereotypies happen in over 5% of the total animal life or for about 10% of its active life and when referring to abnormal behaviour, mal-adaptiveness and suffering are criterion frequently used (Price, 2003).

Despite the fact that researches had led to increase knowledge of the causes of various abnormal behaviour in animals in confinement, the adaptive significance and function of these behaviours are repeatedly not well understood. For instance, wool-biting in domesticated sheep could be a re-directed foraging behaviour due to lack of foraging materials (Vasseur *et al.*, 2006) while the stereotypies of vacuum chewing and bar-biting in tethered or stalled sows may be as a result of reactions arising from controlled feed intake (Lawrence and Terlouw, 1993).

Abnormal behaviours habitually found in pig production include:

2.5.2.1 Tail Biting

Tail biting regularly occurs in growing-finishing stage than among other production stage in pig production and it is one of the most harmful adverse behaviour categorised as cannibalism in pigs. The occurrence of tail biting in pigs have been stated to be about nine percent in undocked pigs which was higher than three percent reported for docked pigs. Biting of tail is a prevalent adverse behaviour in pigs with considerable economic and animal welfare consequences (Bracke *et al.*, 2004a, b).

According to Schroder-Petersen and Simonsen (2001), there were two distinguishable stages noticed in tail biting; the injury stage and pre-injury stage. There is no tail damage observed during pre-injury stage unlike tail damage and bleeding experienced at the injury stage. Most frequently, until the occurrence of tail damage at the injury stage, biting of tail is not noticed nor managed (Schroder-Petersen and Simonsen, 2001). In minimising negative effect of tail biting, it's important to recognise it prior to any tail damage and bleeding. This is required because most pigs get easily attracted to blood and other tissue.

Predominantly, there is little understanding of the causes of tail biting, but generally believed to be associated with a number of factors which includes: discomfort, lack of environmental enrichment, and malnutrition (Bracke *et al.*, 2004a, Brunberg *et al.*, 2011). In addition, over- crowding, high air speed or draught, carbon dioxide or high ammonia concentrations, low-salt diets, deficiency in iron and inadequate drinker and/or feeder space have all been found to be related with tail biting (Bracke *et al.*, 2004a). In view of the fact that tail-biting can be influenced by numerous factors, the problem therefore has no particular solution. Practically, isolation of affected pigs is done as soon as injuries on tail are noticed. Timely elimination of the tail biters and affected pigs is important in the prevention of tail biting epidemic in a sty, this is necessary as it is tough to prevent tail biters from more tail biting once blood have been tasted because of pig's preference to taste of blood (Brunberg *et al.*, 2011).

2.5.2.2 Belly Nosing

Belly nosing falls in the category of stereotypy; this is a recurring, non-functional behaviour. It is one of the frequent abnormal behaviours in piglets that are early-weaned. When weaning was done at about 12 to 14 days old, frequency of belly nosing is as twice or thrice the intensity of piglets weaned between the ages of 21 to

28 days (Worobec *et al.*, 1999). Piglets that are weaned early can use 15 to 25 minutes of a day performing belly-nosing (Widowski *et al.*, 2008). Belly nosing can also occur in growing pigs but the frequency is much decreased than with piglets (Li *et al.*, 2012).

In piglets that are early-weaned, belly nosing has been suggested as a symptom of stress due to early sow removal (Worobec *et al.*, 1999: Weary *et al.*, 1999), whereas its resemblance to udder massage during suckling indicates that the stimulus is associated with hunger and feeding. Due to low intake of solid feed post-weaning, belly nosing happens in the first few days, but highest at about 2–3 weeks of age (Worobec *et al.*, 1999), therefore the connection between belly nosing and hunger is questionable. In another hypothesis, the incidence of belly nosing revealed a spur to massage the udder, without any relationship to hunger and feeding, and that the delay in its occurrence is an indication of learning period (Weary *et al.*, 1999).

According to Widowski *et al.* (2008), pigs exhibiting belly-nosing habitually eat for a lesser time and have a slower growth than the others. Fortunately, to lower incidence of belly-nosing, liquid feeding was found useful and this also enhance the growth rate of piglets newly removed from the sow (Orgeur *et al.,* 2003). Likewise, provision of enrichment to growing pigs and nipple drinkers as compared to bowl drinkers have been said to decrease belly nosing (Torrey and Widowski, 2004). However, lesions on the recipient pig can be as a result of belly nosing for a longer time.

2.5.2.3 Facial, Oral and Nasal Behaviour

The incidence of facial, oral and nasal behaviours (FON) frequently occur in in-gilts or in-sows which is a form of stereotypic behaviour associated with inadequate feeding and barren environments. While the reason and effect of FON is still debatable, FON was presumed a sign of poor welfare. When housed in group, sows were found spending less time in performing FON contrary to those in individual gestation pen. Pregnant pigs in stalls possibly will use up to 30 percent of their time observing (Broom *et al.*, 1995), which contradict the findings of Dailey and McGlong (1997) who found no differences with sows kept indoors in stalls and those on pastures. They indicated that FON may possibly not be a demonstration of poor welfare in sows but related to innate pre- and post-feeding behaviour, rooting and chewing activities. *Ad-libitum* feeding of sows with high fibre containing feeds, reduces the occurrence of FON in sows confined individually or in groups (O'Connell, 2007), as well as provision of environmental enrichment because of its association with barren environment.

2.5.2.4 Piglet Savaging

This is the behavioural killing of piglets after farrowing by sows, and this had been classified as cannibalism. Savaging at the first farrowing is an indication of higher risk in subsequent farrowing compared to those that in their first farrowing did not savage. The occurrence of piglet savaging has been reported to be higher in gilts than in sows with about 0.3 percent in both (Harris *et al.*, 2003). However, constant lighting in the farrowing pen could decrease occurrence of piglet savaging in gilts (Harris *et al.*, 2003).

2.5.3 Other Behaviours in Pigs include:

i. Nose thrusting: this is an occurrence in which pigs continually thrusts the tip of its snout into the belly area or other part of the body of a resting pig, until the resting pig leaves it position.

ii. Rubbing: this is consistent rubbing of pigs' snouts on the flanks area of other pigs leading to injury

iii. Stereotypies: for example; ear biting and sucking, possibly will be linked to reduced quantity of fibre in the feed (Meunier-Salaün *et al.*, 2001) however, rubbing of snout or belly nosing in piglets may possibly not associated with stress or diet quality, but may possibly be linked to the weaning age (Gardne *et al.*, 2001) and barren environment.

iv. Abnormal mating and maternal behaviour

v. Abnormal dunging behaviour

vi. Behaviour of sick pigs: Sick pigs habitually exhibit behaviours different from healthy ones (Millman, 2007). These may include isolation from other animals, decreased drinking, and increased shivering, resting and huddling.

Abnormal behaviours of pig are implication of the mental health of the animals and these are not difficult to observe. Nevertheless, adverse behaviours, like ear and tail biting, belly nosing and stereotypies, might be redirected nosing or rooting behaviour induced by lack of opportunity in the modern housing (Beattie *et al.*, 2000).

2.6 Effects of Stress in Pigs

Generally, stress can be described as any factor that disrupts the internal balance of an animal (Mawdsley and Rampton, 2005). When stress occurs, physiological processes are initiated in order to restore homeostasis, but this can also have negative effects on productivity. The post-weaning phase involves several significant stressors, including environmental factors (such as changes in ambient temperature), psychological factors (such as mixing with other littermates), nutritional factors (such as the removal of sow's milk) (Campbell *et al*., 2013). These stressors cause a significant decline in feed intake. Weaning-related loss of appetite is characterised by notable disturbances in the gastrointestinal tract (GIT), resulting into decline in digestive and absorptive efficiency. This can lead to a rise in harmful bacteria population (Lalle's *et al*., 2004). Additionally, stress from overcrowding reduces immune function by either reducing the number of immune cells or increasing processes that suppress the immune system, ultimately resulting in decline in growth rates (Khafipour *et al*., 2014).

To ensure optimal growth performance in piglets, it is crucial to implement suitable husbandry practices and nutritional management that minimize stressful conditions. During the weaning process, piglets are subjected to various stressors, including interactions with piglets that are not familiar, exposure to ambient temperatures that are not favourable, low levels of biosecurity and contaminated air. The cumulative and synergistic influence of these stressors amplifies their harmful consequences on the growth of pigs (Hyun and Rodney, 1998). Therefore, reducing the number of stressors present in pigs' environment will contribute to improving their overall health.

Following abrupt weaning, piglets display behavioural reactions that lead to negative interactions with new pen mates, often exhibiting abnormal behaviours like belly-nosing (Dybkjaer, 1992). This mal-adjustment can give rise to negative behavioural patterns, such as chewing on other pigs’ tails or ears, as well as belly nosing (Blackshaw, 1981). Dybkjaer (1992) proposed that these unfavourable patterns of behaviour, along with physiological responses like increased corticosterone levels and altered intestinal functions, serve as indicators of poor welfare in weaned piglets.

2.7 Nutritional Stress at Weaning

During weaning, the gastrointestinal tract of piglets undergoes both structural and functional adjustments to facilitate their change from milk-based diet to solid diet predominantly composed of grains (Pluske *et al*., 1995). Conventionally, it is a practice to let piglets feed on solid feed, known as creep feed in the period of lactation. Nevertheless, the intake of creep feed is affected by the digestive system's development and nutrient requirement of piglets. Before the age of eighteen days, both the amount consumed and the litter's percentage consuming creep feed are typically low (Metz and Gonyou, 1990; Sulabo *et al*., 2010). Higher levels of corticosterone, a physiological indicator of stress response, are observed in piglets that feed on little or no creep feed before weaning, indicating a clear association between stress and dietary alteration (Mason *et al*., 2003). Available proof suggests that the adaptation in morphology of intestine is stimulated by the reduction in corticosterone, implying that piglets that quickly adapt experience a lower level of corticosterone during the weaning process (Yao *et al*., 2011).

Low consumption of creep feed leads to a sudden transition from milk-based diet to solid feed, causing a reduction in the villus height in small intestine, a phenomenon known as villi atrophy (Hedemann *et al*., 2007; de Souza *et al*., 2012). A positive correlation has been established between villus height in the small intestine at the time of weaning, and the subsequent daily weight gain post-weaning, suggesting that atrophy of villi negatively affects rate of growth (Pluske *et al*., 1995). Immediately after weaning, the intestinal tract is yet to be capable of producing all necessary enzymes for digesting solid feed, potentially leading to malnutrition due to impaired nutrient absorption and transport in the initial phase of post-weaning (de Souza *et al*., 2012).

The atrophy of villi impacts the mucosal lining, leading to scours after weaning, which is a reaction to higher loads of bacteria resulting from weakened mucosal lining (Pluske *et al*., 1996). Feed availability in the intestinal cavity contributes to stimulating the development of the intestines (Pluske *et al*., 1996). This indicates that, piglets that continue to consume feed shortly after weaning can sustain the villus height as well as the cryptal depth in the small intestine (Pluske *et al*., 1995). As the small intestine undergoes developmental process, with digestive enzymes becoming functional about ten days after birth, it is beneficial to encourage piglets to feed on creep feed starting from this age in order to minimize the negative effects of nutritional stress after weaning on intestinal process (de Souza *et al*., 2012).

When weaning is done in-between the age of 20 and 28 days, the stress experienced by piglets can be reduced by feeding on creep feed pre-weaning and solid feed post-weaning (Weary *et al*., 2008). Efforts have been made to establish a connection between feed intake pre and post-weaning in relation to age (Worobec *et al*., 1999). Piglets that are older tend to have more feed intake compared to piglets at age of four weeks. This is because piglets that are weaned at an older age (six weeks or more) are more likely to consume solid feed compared to those that are weaned at a younger age (Fraser, 1978; Pajor *et al*., 2002).

2.8 Social Stress at Weaning

The termination of interaction between the sow and piglet during abrupt weaning induces considerable distress in both the sow and piglet (Barnett *et al*., 2001). Understanding the impact of weaning at different ages has proven challenging, despite numerous studies examining the age at weaning in piglets (Mason *et al*., 2003). Therefore, limited knowledge exists regarding the specific effects of weaning at various ages on maternal separation.

Apart from being separated from the sow, piglets may also face separation from litter mates and also be compelled to form social hierarchies and interactions with piglets that are not familiar and not their litter mates. This process of forming new hierarchies often involves negative behaviours and is closely linked to stress. Aggression towards piglets can serve as an indicator that they are struggling to adapt to the alterations experienced during weaning (Pajor *et al*., 1999; Hotzel *et al*., 2011).

2.9 Behavioural Outcomes of Weaning Stress

In the later stages of lactation, piglets exhibit natural behaviours by stimulating nursing through the act of massaging the udder of the sow. Belly nosing refers to the distinct up and down rhythmic motion of the snout of one piglet, rubbing the belly of another piglet. It is recognised as a redirected behaviour resulting from nursing stimulation (Fraser, 1978). Continuous belly nosing could lead to flank and belly lesions on the receiving piglet (Straw and Bartlett, 2001), and it is believed to be suggestive of stress caused by separation from the dam (Jarvis *et al*., 2008). It has been observed that piglets engaging in, as well as receiving belly nosing experience reduced growth (Fraser, 1978), indicating that redirected behaviours can have a negative impact on production. Intense fighting between unfamiliar piglets is another aggressive behaviour observed after weaning as they establish a hierarchy (Hotzel *et al*., 2004). Agonistic interactions, including displacement and chasing, result in reduced intake of feed when piglets are transitioned to a restricted environment post-weaning (Gonyou *et al*., 1998). Aggressive behaviour causes a reduction in weight gain and feed conversion efficiency in older pigs, and may also have an effect on piglets during the weaning phase (Jarvis *et al*., 2008). This highlights the clear connection between behaviour and production outcomes.

The impacts of weaning on performance have been primarily examined in relation to negative behaviours, with limited focus on their direct impact. However, a notable correlation has been observed between undesirable behavioural patterns and growth performance when compared. In contrast, positive behaviours such as non-aggressive feeding and play behaviours in piglets have not been extensively studied as a basis for comparing different weaning strategies. As a result, it remains unclear whether piglets exhibiting positive behaviours demonstrate better performance outcomes.

Although negative behaviours are commonly observed post-weaning, nevertheless, the influence of lactation housing on the manifestation of these behaviours is not well-established. Different types of lactation housing might offer an environment that enables piglets to better cope with the usual stress experienced during weaning, resulting in piglets with improved abilities to manage their stress responses (Pajor *et al*., 1999). Play behaviour plays a significant role in pigs' behavioural development and is considered a sign of good health (Fraser, 1990). To date, studies on weaning have primarily concentrated on the observation of play behaviours (Blackshaw *et al*., 1997), while the investigation and analysis of positive behaviours as well as their variations attributed to housing types and weaning have been lacking. The connection between piglet-directed behaviours and stress responses are yet to be documented (Widowski *et al*., 2008), although evidence from performance and injury scores indicates that such a connection may exist. Widowski *et al*. (2003) found that aggressive behaviours occur when piglets' well-being is compromised, suggesting that they can serve as signs of poor welfare.

2.10 Physiological Outcomes of Weaning Stress

Elevated anxiety in piglets at weaning is often accompanied by increased levels of plasma corticosterone, as observed in a study by Dantzer and Mormede (1981). Stressful situations related to weaning trigger the initiation of hypothalamus-pituitary-adrenal (HPA) axis, resulting in elevated corticosterone levels and a decrease in glucocorticoid receptors in the hippocampus (Jarvis *et al*., 2008). Decrease in glucocorticoid receptors leads to higher basal plasma glucocorticoids, such as corticosterone, which activate an anti-stress response while suppressing immunity (Young and Vazquez, 1996). When the immune system of piglets is compromised, their immune response is suppressed. Piglets rely on intake of colostrum in the first 48 hours post-natal to receive maternal antibodies, which provide protection against diseases for a duration of 1-12 weeks, depending on the specific pathogen (Konstantinov *et al*., 2004). However, piglets under 24 hours old do not receive any antibody protection and depend mainly on hygienic conditions within the farrowing crates. As lactation progresses, the level of maternal antibody protection decreases, and after weaning, it no longer provides immune support. Since piglets have limited exposure to new environments, they are vulnerable to new microbes and are more susceptible to illnesses because of their lack of previous exposure (Konstantinov *et al*., 2004). The post-weaning housing conditions typically lack the same level of hygiene as farrowing crates, increasing the risk of disease transmission among piglets. Their compromised immune system, combined with their lack of exposure to new environments, makes them more susceptible to acquiring diseases, particularly gastrointestinal diseases. This vulnerability is further exacerbated when coupled with weakened intestinal function (de Souza *et al*., 2012).

2.11 Impact of Weaning on Performance

Creep feed inclusion in the diet of piglets pre-weaning has been shown to have an influence on their gastrointestinal function during the weaning process. Kuller *et al*. (2004) discovered that piglets which consumed creep feed during lactation exhibited significantly greater uptake in the small intestine when compared to those that did not consume creep feed. Gradually introducing creep feed allows for a smoother transition in the intestine, enabling the adaptation of the villi to the new diet without affecting intake of nutrient, as digestion of milk can still occur (Berkeveld *et al*., 2009). This gradual incorporation of solid feed could as well lower the expenditure of energy required for adaptation, potentially minimising or getting rid of the growth check that occurs post-weaning (Berkeveld *et al*., 2009). The older piglets that are weaned at the age of six weeks, exhibit higher feed intake when compared to younger piglets weaned at 3-4 weeks. This difference can be attributed to the developmental changes in their intestinal structure, enabling them to more effectively consume solid feed (Fraser, 1990). The intake of creep feed directly influences the growth performance of piglets, which is the second most essential attribute in a growing herd, following feed efficiency. Piglets that consume less feed tend to have slower growth rates when compared to those with higher feed intake. Several studies have found a positive connection between pre-weaning feed intake, particularly in gradually weaned piglets, and post-weaning performance (Berkeveld *et al*., 2007). Though intermittent suckling may lead to reduced weaning weights as well as reduced daily weight gain in the period of lactation, the higher daily weight gain observed post-weaning generally makes up for the initial effects (Kuller *et al*., 2004). To be more specific, a decrease in weaning weight resulting from a gradual weaning process does not have a detrimental impact on growth in the initial week post-weaning. This implies that, growth immediately following weaning primarily relies on the piglets' ability to adapt to solid feed other than their weight at weaning (Kuller *et al*., 2004). While these outcomes indicate that overall performance may not be improved, it is worth noting that a gradual weaning process can still contribute to enhanced welfare and remains an important aspect of piglet management.

2.12 Stressors during Weaning

Weaning presents the pig with various challenges at the physiological, environmental, and social levels, which can increase its susceptibility to diseases and production losses. It is a highly stressful period that triggers changes in the pig's intestines, immune system, and behaviour. Numerous stressors are encountered during weaning, including sudden removal from the sow, stress associated with handling and transportation, introduction to a new source of food, social hierarchy challenges, mixing with weaned pigs from different litters, exposure to a physically different environment (for example; farm, building, room, water supply), heightened exposure to pathogen, and exposure to new environmental or dietary substances. The newly weaned pig must quickly adjust to these stressors in order to maintain productivity and efficiency. However, when cumulative weaning stressors become overwhelming for the newly weaned pig, it can result in reduction in performance and increase in mortality rates (Campbell *et al*., 2013; Pluske *et al*., 2018).

2.13 Feed Intake and Weaning

The gastrointestinal tract performs several important functions, including the metabolism and uptake of electrolytes and nutrients, regulation of fluid balance in the body, synthesis of immunoglobulins, digestive enzymes, mucin, and other components, as well as acting as a protective barrier in resistance to antigens and pathogens. However, when weaning the piglet, it undergoes a sudden transition from consuming highly palatable and digestible milk from its mother, which is provided at regular intervals all through the day, into a solid and less digestible dry diet. Consequently, there is a typically a reduction in intake of feed immediately after weaning, leading to malnutrition and a decrease in the rate of growth of the piglet. Le Dividich and Sève (2000) reported that the degree as well as the duration of reduction in feed intake can vary. At the end of first week after weaning, it is estimated that intake of metabolisable energy is approximately 60-70% of the pre-weaning intake of milk. Therefore, it takes about 2 weeks after weaning to recover fully and reach the pre-weaning metabolisable energy intake level. In a study by Spreeuwenberg *et al*. (2001) that examined the connection existing between low intake of feed intake and different composition of diets (lactose/protein ratios) on small intestinal barrier function, it was found that during the initial 4 days after weaning, diet composition was not as significant in maintaining intestinal barrier function. Instead, continual low feed intake played a more crucial role in predisposing pigs to intestinal barrier malfunction. Another study by McCracken *et al*. (1999) revealed that reduced intake of feed after weaning could add to intestinal inflammation, negatively impacting the height of villi and depth of crypts, ultimately leading to reduced growth performance.

Typically, pigs experience a weight loss of around 100-250 grams on the first day post-weaning, irrespective of their age at weaning. However, they tend to recover this weight loss by approximately 4 days after weaning. Tokach *et al*. (1992) stated that weight gain during the first week post-weaning has an impact on the total number of days it takes pigs to get to market weight (around 110 kg body weight). Pigs that gained more than 227 grams per day in the first week post-weaning got to market weight about six to ten days earlier when compared with pigs that gained between 0 grams per day and 150 grams per day during the same period. It is therefore crucial to encourage pigs to eat and grow as fast as possible post-weaning. While it is challenging to avert some reduction in body weight as pigs transition from sow's liquid milk to solid starter diet, comprehending the problems as well as the consequences of low intake of feed associated with weaning and its later effect on performance could assist nutritionists in designing diets that utilize additives and feed ingredients known to increase feed intake. Additionally, it can help producers implement techniques to mitigate weaning stress.

2.14 Structure and Functional Changes of Intestine and Weaning

In addition to experiencing reduction in intake of feed, weaned pigs undergo physiological modifications in the function and structure of their intestines. These changes include alterations in enzymatic activities and uptake or secretion processes. According to Pluske *et al*. (1997), these physiological modifications can affect the uptake capacity of the small intestine, potentially influencing feed efficiency. According to Pluske *et al*. (1997), weaning triggers both long-term and immediate functional and structural changes in the small intestine. These changes include a reduction in villi length (atrophy of the villi), and an increase in crypt depth post-weaning. According to Hampson (1986), the villus height can quickly reduce by approximately 25% to 35% of its pre-weaning level in the space of the initial 24 hours in pigs that are weaned at 21 days of age. The decline in the villous height persists for approximately five days following weaning, resulting in villi that are only about half their initial height. Concurrently, changes in crypt elongation occur at a slower pace, spanning the first eleven days after weaning. Montagne *et al*. (1986) examined various intestinal markers that are associated with weaning, which may serve as a basis for research aimed at mitigating the physiological changes that accompany the weaning process. Weaned pigs also experience a reduction in the activity of brush-border digestive enzymes. Lalles *et al*. (2004) observed reduction in the activity of amino-peptidase and lactase from day 2 to 15 after weaning. Maltase activity exhibited a decline for 2 days post-weaning, followed by an increase from day eight to fifteen after weaning. Furthermore, pancreatic secretions exhibited a temporary decline until day 15 post-weaning, after which amylase and trypsin activity began to increase. Early weaned pigs experience a reduction in alkaline phosphatase, an enzyme involved in detoxifying bacterial lipopolysaccharide endotoxin, and influencing intestinal inflammation. These changes can affect the digestive, absorptive, and secretory ability of the small intestine, ultimately compromising its barrier function. As a result, post-weaning diarrhoea and inflammation associated with weaning may occur. In addition to the compromised digestive and absorptive ability, weaning also has a negative impact on the integrity of the intestinal barrier. The epithelial layer that lines the small intestine acts as the body's primary defence against harmful microorganisms, toxins, and antigens present in the intestinal cavity. When the integrity of the intestinal barrier is compromised, it leads to increased permeability, allowing bacteria, toxins, or antigens associated with feed to pass through the epithelium. This can result in impaired nutrient uptake, diarrhoea, inflammation, reduction in growth and production. A study by Nabuurs *et al*. (1994) examined the effects of weaning as well as Escherichia coli infection on the absorptive ability of the pigs' small intestine. The pigs were either weaned at the age of 30 to 32 days, or kept with the sow without weaning, and segments of the small intestine were infected with Escherichia coli using perfusion procedures. No variations were observed in the uptake of fluid, chloride, or potassium in unweaned non-infected pigs. However, weaned pigs that were uninfected with Escherichia coli showed reduced fluid uptake on days 4, 7, and 14, as well as decrease in sodium and chloride uptake on days 4 and 7 in the segments of the intestinal when compared with the segments from unweaned uninfected pigs. In the Escherichia coli infected intestinal segments of weaned pigs, fluid uptake was lower on days 11 and 14, and potassium and sodium absorption was lower on day 11. Furthermore, chloride uptake was reduced on days 4 and 11 when compared to infected segments from unweaned pigs.

2.15 Hormonal Control of Reproduction during Lactation

After farrowing, pigs experience a phase of reproductive inactivity called anovulation, which generally continues until the piglets are no longer nursing. This phase is commonly known as lactation anoestrus. Lactation plays an essential role in regulating the timing of heat and ovulation during this period, primarily because the piglets' actions of suckling and stimulating the teat trigger the release of milk. Mature sows undergo an oestrus cycle that typically repeats every 21 days, although it can vary in length between 18 and 22 days (Knox and Wilson, 2007). This cycle is in two phases namely; a luteal phase lasting 13 to 15 days, as well as a follicular phase lasting 5 to 7 days. The luteal phase starts around the second day after the onset of oestrus, marked by an increase in progesterone levels, and generally continues till the fifteenth day of the cycle when progesterone levels decline (Knox and Wilson, 2007). The follicular phase starts approximately 5 to 6 days prior to oestrus, and it is characterized by reduced levels of plasma progesterone as well as an increase in oestrogen (Knox and Wilson, 2007).

The synthesis of gonadotropin-releasing hormone (GnRH), which subsequently leads to the synthesis of luteinizing hormone and follicle-stimulating hormone, can be influenced by various factors in both the external and internal environment. The sow's age, its metabolic status, and overall health condition can have an impact on the synthesis of gonadotropin-releasing hormone (Prunier and Quesnel, 2000). Additionally, external environmental factors namely; light, nutrition, temperature, physical and social surroundings could also have an influence (Prunier and Quesnel, 2000). Nevertheless, the most significant exogenous environmental factor is often the hindering effect of suckling on the synthesis of GnRH, consequently affecting the cyclical activity of the ovaries.

2.16 Hypothalamic-Pituitary-Ovarian Axis

The anterior pituitary gland synthesizes luteinizing hormone and follicle-stimulating hormone, which are regulated by the release of gonadotropin-releasing hormone from the hypothalamus. Furthermore, the synthesis of luteinizing hormone and follicle-stimulating hormone is influenced by the feedback effects of endogenous opioid peptides and ovarian steroids (Knox and Wilson, 2007). The duo of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) play crucial roles in follicle maturation, but follicle-stimulating hormone has a greater impact during the early stages of growth, typically up to 2-3mm, while luteinizing hormone becomes more influential during the later stages of follicular growth, particularly beyond 4mm (Driancourt *et al*., 1995). Zeleznik *et al*. (1974) stated that, under the influence of follicle-stimulating hormone (FSH), the granulosa cells start producing LH receptors, rendering the follicle responsive to stimulating impacts of luteinizing hormone. Immediately the antral follicle becomes receptive to luteinizing hormone, the secretion of follicle-stimulating hormone is blocked due to negative feedback mechanisms initiated by estradiol and inhibin produced by the follicle itself. As a result, the follicle continues to mature towards the pre-ovulatory stage (Sullivan *et al*., 1999). Oestrogens, especially estradiol-17beta, synthesized by the follicles, act as inhibitors of luteinizing hormone secretion. Nevertheless, when estradiol levels rise and get to a specific threshold, it switches to a positive feedback process on the hypothalamus, triggering a substantial gonadotropin-releasing hormone surge (Knox and Wilson, 2007). Successive release of gonadotropin-releasing hormone from the hypothalamus prompts the adenohypophysis gland to synthesize pulses of luteinizing hormone preceding ovulation, typically occurring approximately 40 hours before ovulation takes place. The pre-ovulatory surge of LH serves as the trigger for ovulation itself (Knox and Wilson, 2007). Progesterone and low levels of estradiol during the luteal phase sends a negative feedback to the hypothalamus, suppressing the secretion of gonadotropin-releasing hormone (Knox and Wilson, 2007). The hypothalamus releases small pulses of gonadotropin-releasing hormone as the progesterone level decreases, which allow for the release of luteinizing hormone and follicle-stimulating hormone from anterior pituitary, initiating the next follicular growth cycle (Prunier and Quesnel, 2000).

2.17 Environmental Factors that Affect Reproduction during Lactation

2.17.1 Suckling Piglets

The mechanism of removal of milk from the udder, via neuroendocrine reflex, has been a subject of interest among scientists for some years (Fraser, 1980). The generated afferent impulses via various forms of teat stimulation by the piglets (such as tactile, visual and auditory cues), travel to the hypothalamus. In response, release of oxytocin into the bloodstream is done via the triggering of the posterior lobe of the pituitary gland (Grant, 1989). Once oxytocin enters the bloodstream, it reaches the myoepithelial cells in the mammary glands, leading to their contraction. This contraction facilitates the release of milk from the alveoli as well as its passage through the larger ducts before eventually getting to the teat (Grant, 1989). The neuroendocrine reflex triggered by suckling suppresses gonadotropin-releasing hormone release, as well as luteinizing hormone and follicle-stimulating hormone, during lactation. This reflex is primarily responsible for lactation anoestrus, or the absence of oestrus behaviour, in lactating animals (Varley and Foxcroft, 1990). Suckling piglets hinder the secretion of GnRH, leading to a reduction in ovarian activity and the absence of behavioural oestrus. Nevertheless, the influence of the suckling stimulus reduces as lactation progresses, and the sensitivity of the gonadotropin-releasing hormone pulse generator in the hypothalamus decreases. This reduction in sensitivity may be due to a decrease in the presence of endogenous opioid peptides acting on the hypothalamus. As a result, concentrations of gonadotropin-releasing hormone, luteinizing hormone and follicle-stimulating hormone gradually increase due to the hypothalamic-pituitary-ovarian axis (HPA-axis) recovery (Soede *et al*., 2011). Opioid system plays a significant part in lactation anoestrus through hindering the synthesis of GnRH in the hypothalamus, thus suppressing the release of luteinizing hormone (Cosgrove *et al*., 1993).

2.17.2 Nutrition

Nutritional impact on sows' reproductive performance has been thoroughly examined and summarized in previous research (Prunier and Quesnel, 2000). Due to selective breeding for leaner and more productive finisher pigs, the appetite of sows has reduced, resulting in challenges in finding the right balance between sow reproductive capacity and consistent growth of finisher pigs (Bergsma *et al*., 2009). The critical limit wherein losses of body protein and fat ratio begin to have negative impacts on reproductive capacity has been thoroughly researched and recorded (Clowes *et al*., 2003a, b). When the nutritional intake alone is insufficient to meet the demands of milk production, lactating sows will utilize their body reserves, resulting in a catabolic state. If significant losses occur, particularly in body protein rather than body fat, it can result in fertility issues (Kemp *et al*., 2011). Increasing the feed intake of lactating sows make it capable of curbing excess losses of body protein, and this has also been proposed to result in higher litter weights at weaning. Nevertheless, there is an energy input limit beyond which further growth of the litter is not observed (Bergsma *et al*., 2009). According to Rojkittikhun *et al*. (1992), lactating sows that mobilize a larger proportion of body nutrient reserves have been proposed to prioritize energy for production of milk, causing a higher litter growth rates when compared to sows with lower weight loss in the course of lactation. Also, Pluske and Dong (1998) indicated that first-parity sows that exhibited anabolic condition in the later part of lactation period, directed nutrients towards maternal body tissues other than production of milk. Bergsma *et al*. (2009) defined this phenomenon as sow's lactation efficiency, referring to the balance between the sow's energy input as well as litter output with respect to growth. Sows that exhibit higher lactation efficiency achieve this by consuming less feed and experiencing lower fat losses, resulting in increased litter growth and reduced piglet mortality. On the other hand, sows that are less efficient in the course of lactation, even when fed up to 90% of their expected feed intake, demonstrate better production of milk as indicated by the gain in litter weight. These sows also preserve their body tissues, thus avoiding the detrimental effects of maternal catabolism on the next litter (Patterson *et al*., 2011). However, it is essential to note that there is a complex relationship between the degree of mobilization of tissue employed in support of litter growth as well as its subsequent effects on the following litter. There is significant variation among sows in the way they react to nutrient restriction and catabolism (Patterson *et al*., 2011).

2.17.2.1 Effects of Level of Nutrition during Lactation on Post-weaning Reproductive Outcomes

The regulation of ovarian function is primarily influenced by luteinizing hormone (LH), and extensive research has been conducted to examine the impact of nutrition on LH secretion in both multiparous and primiparous sows (Quensel *et al*., 1998). Numerous studies provide substantial evidence supporting the relationship between nutrition and luteinizing hormone synthesis in the course of lactation (Mao *et al*., 1999). Nevertheless, it is challenging to differentiate the impacts of suckling stimulus from the metabolic needs of a lactating sow on luteinizing hormone secretion. To address this issue, Mullan *et al*. (1991) conducted a comparative study examining the effects of two feed intake levels (*ad libitum* or restricted to 3kg/day) and two suckling intensity levels (six or twelve piglets) on weight loss during lactation, over a lactation period of 21-day, as well as LH pulsatility before and after weaning. In general, when intake of energy is reduced during lactation, it is associated with an extended weaning to oestrus interval as well as decreased plasma luteinizing hormone level post-weaning. Nevertheless, it appears that intensity of suckling has a stronger influence on luteinizing hormone concentration post-weaning (Mullan *et al*., 1991). Thus, the primary factor inhibiting luteinizing hormone synthesis in sows that are lactating is the suckling stimulus, but the sows' nutritional level in this period can compound the effect. In situations where voluntary lactation feed intake is low, it could be possible to sustain the post-weaning reproductive capacity of the sow by reducing intensity of suckling. By doing so, the sow's reproductive capacity after weaning could be adequately sustained (Mullan *et al*., 1991).

In sows subjected to feed restriction, the suppression of gonadotrophic hormones becomes more apparent during later part of lactation, as well as the onset of development of follicles post- weaning can vary (Quensel *et al*., 1998). The nutritional level of the sow according to Mao *et al*. (1999) directly affects LH secretion at the hypothalamus. The study compared the reproductive outcomes of first-parity sows that were fed *ad libitum* all through the lactation period with those fed restrictively at 50% of *ad libitum* feed intake from days 22-28, as well as sows that received both restricted feeding and 800 ng of GnRH at 6-hour intervals during the same period. Feed restriction resulted in decreased LH secretion, but the introduction of exogenous gonadotrophins to sows that were fed restrictedly in the final week of lactation was discovered to revive LH synthesis before weaning, to levels comparable to those of sows fed *ad libitum* (Mao *et al*., 1999). However, despite the restoration of LH secretion, this response did not translate into improved reproductive performance after weaning, as both feed-restricted treatments resulted in a markedly prolonged interval between weaning and oestrus. This suggests the inability of exogenous gonadotrophins administration to remove the negative effects on observed post-weaning performance in catabolic sows.

According to Vinsky *et al*. (2006), weaning to oestrus interval, rate of ovulation, as well as pregnancy rate had no significant difference in primiparous sows subjected to a feed intake restriction of 50% compared to the control sows in-between days 14-21. However, the rate of embryo survival declined by over 10% when the sows were restrictively fed during the final lactation week. Also, findings from Patterson *et al*. (2011) indicated that the first-parity sows subjected to a feed restriction of 60% of their expected feed intake during the final lactation week did not experience any negative effects on rate of ovulation, embryo survival, as well as the embryo count at day 29 of pregnancy, regardless of being in a catabolic state. One possible explanation for lack of negative impact on reproductive outcomes in restricted sows is that, modern sows may possess improved abilities to adapt to unfavourable conditions in the course of lactation, which are attributed to selection against prolonged interval between weaning to oestrus, enhanced sow’s prolificacy, as well as improved quality of litter (Kemp and Soede, 2012).

On the other hand, providing sows with a feed intake of 125% of the *ad libitum* level did not counteract the predominant suckling influence, nor increase the average LH levels, interval between weaning and oestrus, as well as rate of ovulation after weaning, despite inducing an anabolic state in the sows in the course of lactation when compared with the sows fed *ad libitum* or restricted intake (Zak *et al*., 1998). This suggests that while feeding at 125% of the *ad libitum* level resulted in a positive energy balance, it did not override the primary control of LH secretion during lactation exerted by suckling. Therefore, feeding above the *ad libitum* level does not remove the effects of suckling on luteinizing hormone secretion (Zak *et al*., 1998).

2.17.2.2 Lactation Weight Loss

Young sows in their first litter do not get over lactation effects as quickly as the older sows because they are still very much in the process of growing and maturing (Bracic and Skorjanc, 2008). During first lactation, a gilt has only attained around 30-40% of its required body protein mass, and has accumulated less body fat mass. Consequently, if the gilt does not receive sufficient nutrition, her post-weaning reproductive capacity may be compromised (Whittemore, 2003). During lactation, insufficient nutritional intake which leads to a state of catabolism can give rise to various consequences post-weaning, including delay in weaning to oestrus interval, reduction in luteinizing hormone level, decreased rate of ovulation, lower pregnancy rate, as well as diminished embryonic survival (Kemp and Soede, 2012).

Research by Schenkel *et al*. (2010) has shown that a body weight loss exceeding 10% can lead to a decrease in second litter’s size in first-parity sows, emphasizing the essence of enough body reserves during parturition as well as weaning. Thaker and Bikei (2005) reported that, on average, sows can attain a weaning to oestrus interval of less than seven days when experiencing a lactation weight loss of less than 15% of their body weight. The authors categorized sows based on different levels of lactation weight loss, namely <5%, 5-10%, 11-15%, 16-20%, or >20%, and observed a significant impact on weaning to oestrus interval in first-parity sows when their weight losses during lactation exceeded 5%. Nevertheless, the impact was only evident when the weight losses during lactation exceeded 10% for multiparous sows.

2.17.2.3 Sow Protein Losses

During lactation, it is inevitable for sows to experience body weight loss. In the case where a sow that is lactating has a high voluntary intake of feed, its body protein deposits will still be mobilized. Nevertheless, when protein in the diet is not enough, the sow becomes more reliant on mobilizing protein in the body to aid lactation (Clowes *et al*., 2003a). Clowes *et al*. (2003a) aimed to investigate the impact of significant body protein losses on milk production and reproductive process. Their findings indicated that sows can tolerate a loss of between 9-12% of their body protein mass as at the time of farrowing without negatively having effect on the growth of the piglet as well as ovarian function. However, when the body protein loss reached 16%, there were noticeable changes in milk composition and reduction in ovarian function. This was evident in a decrease in protein concentration in milk on twentieth day of lactation and a decline in rate of growth of litter from day 20 until weaning. The adverse effects of high body protein loss were further reflected in altered ovarian function, including reduced follicular fluid volume, a lower number of follicles measuring over 4mm in diameter, and a decrease in uterine weight.

2.17.3 Parity

The reproductive performance of the primiparous sows after initial lactation period is generally regarded to be inferior to that of sows with multiple parities, primarily because of the reduction in their metabolic state (Quesnel *et al*., 2007). Several factors contribute to the reduced reproductive capacity of primiparous sows. Firstly, these sows are still undergoing growth and maturation, which can impact their overall physiological condition. Additionally, they possess a lower capacity for feed intake and possess fewer protein and fat reserves to sustain lactation (Bracic and Skorjanc, 2008). Lactation's demanding nature negatively affects primiparous sows, resulting in longer weaning to oestrus intervals, reduction in ovulation rates, decreased survival of embryo, lower rates of farrowing, and smaller litter sizes (Kemp and Soede, 2012). To enhance the metabolic condition of sows that are primiparous during the period of lactation, a suggested approach is split weaning implementation, where a set of the litter is separated for few days before the regular weaning time (Vargas *et al*., 2009). Split weaning implementation for first-parity sows by separating a portion of the litter in-between day 18 of lactation and the weaning day, day 21 had a positive impact on their reproductive parameters. In comparison to conventionally weaned sows, split-weaned sows had more numbers of follicles measuring 3mm or larger, a day after weaning (Zak *et al*., 2008, Saikia *et al*., 2017). This, led to an earlier return to oestrus after weaning for sows that were split-weaned compared to conventionally weaned sows, with a mean difference of 4.6 days versus 5.7 days, respectively (Zak *et al*., 2008).

2.18 Intermittent Suckling

Intermittent suckling is defined a system where a whole litter is separated from their dam for some hours per day during lactation. It is a gradual weaning process that imitates the increasing hours a sow spends away from its piglets in the wild. Intermittent suckling has been reported to make early weaning a stress free event for piglets (Weary *et al*., 2002). Intermittent suckling increases feed intake by piglets and eliminates physiological and behavioural changes indicative of compromised welfare post-weaning (Berkeveld *et al*., 2009; Diana *et al*., 2016). This is because piglets are forced to explore other sources of nutrients (creep feed) when they do not have access to suckling milk during the period of separation. The practice of intermittent suckling aims to reduce the amount of milk ingested by piglets, encouraging them to feed more on solid feed during lactation in order to satisfy their energy needs. Research has revealed that intermittent suckling leads to increased consumption of creep feed when compared to piglets housed with the sows in a conventional farrowing crate throughout lactation (Gerritsen *et al*., 2008; Berkeveld *et al*., 2009). Nevertheless, piglets subjected to gradual weaning are lighter at the time of weaning because of the sudden introduction of intermittent suckling, which involves separating the piglets from the sow, for six hours or more. There is limited understanding on how piglets react to different intermittent suckling durations, and it remains uncertain whether a shorter period of intermittent suckling may yield greater benefits.

Millet *et al*. (2008), in contrast to the aforementioned studies, presented findings that differed. They observed that piglets that were in the intermittent suckling group were able to adequately consume milk when they had access to the sow, resulting in limited consumption of creep feed and no significant gradual weaning effect on post-weaning performance. In the study, piglets were separated from the sow for seven hours per day, beginning at two weeks pre-weaning. This duration of separation allowed milk intake to remain unaffected, ensuring consistent weight gain in the course of lactation. These findings suggest that longer separation period may be necessary to encourage creep feed consumption and promote gut development.

Intermittent suckling has also been reported to reduce weight loss in sows during lactation as well as weaning to oestrus interval (Kuller *et al*., 2004). Sows are often catabolic and losses weight during lactation because their feed intake is not always enough to meet up with the nutrient requirement for milk production. Therefore, the sow mobilises the tissue reserves thereby losing weight. However, the period of separation reduces suckling by the piglets which leads to reduction in milk production, loss of weight, as well as weaning to oestrus interval. Intermittent suckling being used as a method to trigger lactation oestrus has been explored, and it has shown response rates of about 28% (Langendijk *et al*., 2009). The effectiveness of intermittent suckling in triggering lactation oestrus is influenced by various factors, including the duration of sow-litter separation, the timing in relation to parturition, and the number of days it is practiced before completely weaning the piglets (Gerrritsen *et al*., 2008a). Furthermore, the breeding and parity status of the sow play a significant role, as a higher percentage of sows with multiple parities have shown lactation oestrus response to intermittent suckling when compared with first-lactation sows (Soede *et al*., 2012).

2.18.1 Luteinising Hormone and Follicle Growth Resulting from Intermittent Suckling

Normally, lactating sows experience anoestrus with minimal pulsatile LH release. Nevertheless, intermittent suckling could trigger an instant increase in the release of LH when a sow is separated from its piglets (Langendijk *et al*., 2007). Concurrent with this rise in LH release, there is evidence that follicle diameter increases in response to intermittent suckling. Gerritsen *et al*. (2008) reported that the extent of follicular development as well as ovulation stimulation is influenced by the timing of initiation of intermittent suckling after parturition. In their study, sows that commenced intermittent suckling on day 21 of lactation had a greater number of pre-ovulatory follicles compared to those that started on day 14 (100% vs. 87%, respectively). Also, a higher percentage of the sows ovulated within eight days of intermittent suckling initiation (75% on day 14 vs. 94% on day 21). However, Langendijk *et al*. (2009) observed no significant differences in FSH concentration, FSH pulses, or FSH amplitude between sows that experienced ovulation in response to intermittent suckling and those that did not. This finding contrasts with that of Degenstein *et al*. (2006), who reported an increase in FSH concentration following split weaning, which was expected to stimulate higher follicular growth at weaning. Additionally, Langendijk *et al*. (2009) observed no changes in luteinizing hormone and follicle stimulating hormone concentration in response to boar exposure, contrary to expectations. These results suggest that follicle stimulating hormone is not the hindering factor in follicular development. Therefore, sows subjected to intermittent suckling can exhibit follicular development as well as ovulation similar to weaned sows, provided that intermittent suckling is not initiated too early after farrowing.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Description of the Site of Experiment

The studies in this research were carried out at the Piggery Unit of the Teaching and Research Farm, University of Ibadan, Ibadan, Oyo State. The farm is situated in South-western part of Nigeria on longitude 7.47491 and latitude 3.91371, at an altitude of 200-300m above the sea level. The average temperature ranges from 25 °C to 32 °C, humidity 71.53% to 76.00% and an annual rainfall of 1250mm to 1500mm which all characterise a tropical climate.

3.2 Experimental Site Preparation

The experimental sites were inspected for possible damages which were renovated before the commencement of the experiment. The feeders and the drinkers were also confirmed to be in good condition and necessary adjustments were made. The pens were then washed thoroughly and disinfected with 'Izal' disinfectant.

3.3 Installation of Camera and Behavioural Data Collection

Close circuit televisions (CCTV) were installed in the entire sties used in these experiments to monitor the behaviour of the pigs. The video cameras (AHDI Mega Pixel Cameras, CCTV Central, Mount Waverley, Victoria, Australia) with 3.6 mm focal lenses were mounted in the sties at strategic positions that provides a clear sight of the entire sty (Plate 3.1). Observations were continuously recorded using Analogue High Definition (AHD) Digital Video Recorder (DVR) which was connected to the cameras; the DVR was located in the monitoring room away from the pen, so the activities of the operator will not affect the behaviour of pigs. The digital video data were subsequently transferred from the DVR unit to external hard drives in the Audio-Video Interleave (AVI) format. These files were then observed on a laptop computer to compile behaviour data. Recordings were done for four hours a day between 08:00-12:00 hours, for the first 10 days of the duration of the experiment. The behavioural parameters measured in this experiment were generated according to the ethogram in Table 3.1.

Plate 3.1. Cross- section of some of the installed Close circuit televisions (CCTV) used for behavioural recordings of experimental animals during the studies

Table 3.1: Behavioural Ethogram of Swine

Category	Definition
Feeding behaviour	Head in feeder or about 3cm near the feeder (includes nosing the feeder)
Aggressive behaviour	
Biting	Nibbling, chewing or sucking ears, feet, legs or tail of another pig
Chasing or Fighting	The act of one pig chasing another, involving running and following
Manipulative behaviour	
Belly nosing	Nose or mouth in contact with the belly of pen mate
Nosing	Using the snout to rub the body of a pen mate, primarily targeting the back, shoulders, belly, and the areas between the limbs.

Source: Extracted from Pluske and Williams (1996) and Bolhuis *et al.*, (2005)

STUDY ONE: Dam reproductive performance, growth, behavioural and stress responses of weanling pigs to weaning time

3.4 Specific Objectives

To assess different weaning time on weanling pigs' growth, behaviour, stress response and subsequent reproductive performance of the dam.

3.5 Site of Experiment

This experiment was carried out at the Piggery Unit of the Teaching and Research Farm, University of Ibadan, Nigeria.

3.6 Experimental Animals

A total of eighteen sows and seventy two piglets (Largewhite X Landrace) were used for this study. The distribution of the animals into three treatments was done randomly, with each treatment having six replicates (one sow and four piglets/replicate) arranged in a Completely Randomised Design (CRD). A total of 18 pens were used for this experiment. Feeds and water were served two times per day at the hours of 08:00 and 14:00 all through the 30 weeks of the experiment.

3.7 Experimental Layout and Design

The design of the experiment was completely randomised design. Pigs were allotted into three treatments which include:

Treatment 1: Weaning at four weeks

Treatment 2: Weaning at six weeks

Treatment 3: Weaning at eight weeks

3.8 Management of Experimental Pigs

Before the arrival of the animals, the sties and surroundings were washed and properly cleaned. On arrival, the animals were dewormed with Levamisole and Ivermectin which were administered based on their body weight (1.5ml/50 kg body weight) against internal and external parasites respectively. Antibiotics 20% L.A with multivitamins were also administered during the two weeks of acclimatisation; water as well as feed were also given *ad libitum* during this period according to standard practices. After the acclimatisation period, the sows were synchronised to oestrus using prostaglandin F2α, and subsequently mated. Mating date was recorded in order to know the expected date of parturition. The pregnant sows were moved to farrowing pens, seven days to the expected date of farrowing. Three days after farrowing, the piglets were injected 2mls of iron injection intramuscularly (IM). Sows were fed lactation diet from entry into the farrowing pen until weaning. Piglets were offered creep feed from day 14 after farrowing and clean and cool water was provided. All these were done according to standard practices.

3.9 Experimental Ration

The animals used for this experiment were fed concentrates during the twenty-four weeks of the experiment. The gross composition of diet given to the sows, piglets, and weaners are as shown in Tables 3.2, 3.3, and 3.4 respectively.

Table 3.2: Gross Composition of Creep Feed for Piglets

Ingredient	Percentage
Maize	59.00
Groundnut cake	21.00
Soybean meal	14.60
Fish meal	2.00
Di-Calcium Phosphate	1.40
Oyster shell	1.00
Premix	0.25
Methionine	0.25
Lysine	0.25
Salt	0.25
Total	100
Calculated Analysis	
Crude Protein (%)	23.00
Energy (Kcal/kg ME)	3019.27
Crude Fibre (%)	3.30

Table 3.3: Gross Composition of Concentrate for Weanling Pigs

Ingredient	**Percentage**
Maize	46.50
Wheat offal	30.00
Groundnut cake	10.00
Soybean meal	10.00
Di-Calcium Phosphate	1.50
Oyster shell	1.00
Premix	0.25
Salt	0.25
Methionine	0.25
Lysine	0.25
Total	100
Calculated Analysis	
Crude Protein (%)	18.28
Energy (Kcal/kg ME)	2720.50
Crude Fibre (%)	4.53

Table 3.4: Gross Composition of Concentration for Lactating Sows

Ingredient	Percentage
Maize	44.00
Wheat offal	40.50
Soybean meal	2.00
Groundnut cake	10.00
Di-Calcium Phosphate	1.50
Oyster shell	1.00
Premix	0.25
Salt	0.25
Methionine	0.25
Lysine	0.25
Total	100
Calculated Analysis	
Crude Protein %	16.58
Energy (kcal/kg ME)	2510.83
Crude Fibre %	5.23

3.10 Data Collection

Collection of data started immediately after the sows farrowed and they were separated into their respective treatments and replicates. The data collected include farrowing indices of the sows, growth performance, stress and behavioural indices for the weanling pigs, performance and reproductive indices for the sows.

3.10.1 Body Weight Gain, Feed Intake and Feed Conversion Ratio

Provision of feed was done two times per day at the hours of 08:00 and 14:00 daily. Quantity of feed served was weighed and fed to the pigs per replicate and the leftover feed was weighed using a table top weighing scale (Camry, 25 kg). The feed intake was calculated by deducting the leftover from the quantity served as follows:

$$\text{Feed Intake} = \text{Amount of feed served} - \text{Amount of feed leftover} \qquad \ldots\ldots. \quad 3.1$$

Pigs in each replicate were weighed at the commencement of the experiment and on weekly basis using weighing scale. At the termination of the experiment, the total weights gained were determined by deducting the initial body weight from the final body weight. Feed conversion ratio (FCR) was calculated as a ratio of feed consumed to the body weight change and it is expressed as;

$$\text{FCR} = \frac{\text{Average feed consumed}}{\text{Average weight gain}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad 3.2$$

3.10.2 Blood Collection

On the first day of weaning, blood samples (5mls per sample) were collected from the weanling pigs, and subsequently on days 1, 4, 7, 11 and 14. The blood samples used for haematology were collected into bottles containing EDTA (Ethylene di-amine tetra-acetic acid) to prevent coagulation while the blood samples used for serum analysis were collected into plain bottles.

Serum corticosterone was determined using commercially available ELISA kit (Enzo Life Sciences, Cortisol ELISA kit, AD-901-071, Farmingdale, NY) in accordance with the manufacturers' instruction.

The parameters determined for haematology were white blood cells, lymphocytes, monocytes, neutrophils and eosinophils as described by Schalm *et al.* (1975).

3.10.3 Behavioural Parameters

A total of eighteen Close circuit television (CCTV) were used in monitoring and recording the behaviour of the animals in this experiment. Remote operation of camera control equipment and video recorder were placed in a room far away from the pens to ensure the pigs activities were not influenced by operator presence. The behavioural data are according to the ethogram in Table 3.1 and were deduced from the video recordings which include feeding, biting pen mates, chasing pen mates, belly nosing pen mates and nosing pen mates. All these were counted to measure the feeding behaviour, aggressive behaviour, and manipulative behaviour. The counting from the video recordings was done for one minute at each ten minutes, making a total of 24 counts in the four hours of each recording; this is known as Instantaneous Scan Sampling. The frequency of occurrence of each group of observation on the ethogram was then expressed as a percentile of the total observation according to Scott *et al.,* (2006a, b).

3.10.4 Reproductive Parameters

The reproductive parameters measured include weaning to oestrus interval, percentage conception, average litter size, average litter birth weight, average number of piglets born alive and average number of still births (Hines and Loucks, 2020).

3.11 Statistical Analysis

Performance data, reproductive data and haematology data were analysed with one-way Analysis of Variance (ANOVA) using SAS (2010). Means were separated with New Duncan Multiple Range Test, while corticosterone data and behavioural data were subjected to descriptive statistics.

STUDY TWO: Duration of Intermittent Suckling on Growth, Behaviour, Stress Response in Piglets, Weanling Pigs, and Reproductive Performance of the Dam

EXPERIMENT ONE: Duration of Intermittent Suckling on Piglets' Growth, Behaviour, Stress Response and Subsequent Reproductive Performance of the Dam

3.12 Specific Objective:

To investigate the durations of intermittent suckling effect on piglets' growth, behaviour, stress response and subsequent reproductive performance of the dam

3.13 Site of Experiment

This experiment was carried out at the Piggery Unit of the Teaching and Research Farm, University of Ibadan, Nigeria. The farm is situated in South-western part of Nigeria on longitude 7.47491 and latitude 3.91371, at an altitude of 200-300m above the sea level. The average temperature ranges from 25 °C to 32 °C, humidity 71.53% to 76.00% and an annual rainfall of 1250mm to 1500mm which all characterise a tropical climate.

3.14 Experimental Animals

A total of sixteen sows and sixty four piglets (Largewhite X Landrace) were used for this study. The distribution of the animals into four treatments was done randomly, with each having four replicates (one sow and four piglets/replicate) arranged in a Completely Randomised Design (CRD). A total of 16 pens were used for this experiment. Feeds and water were served two times per day at the hours of 08:00 and 14:00 all through the 22 weeks of the experiment.

3.15 Experimental Ration

The animals used for this experiment were fed concentrates. The gross composition of diet given to the piglets and sows are as shown in Tables 3.2 and 3.4 respectively.

3.16 Experimental Layout and Design

The design of the experiment was Completely Randomised Design. The lactation period lasted six weeks and intermittent suckling started on the first day of the fifth week of lactation. Pigs were allotted into four treatments which include:

Treatment 1: Continuous suckling

Treatment 2: Separation for 4 hours/day for 14 days

Treatment 3: Separation for 8 hours/day for 14 days

Treatment 4: Separation for 12 hours/day for 14 days

3.17 Management of Experimental Pigs

The sows were dewormed with Levamisole, administered based on their body weight, and Ivermectin (1.5 ml/50 kg body weight) against internal and external parasites respectively. Antibiotics 20% L.A with multivitamins were also administered. The sows were synchronised to oestrus using prostaglandin F2α, and they were subsequently mated. Mating date was recorded in order to know the expected date of farrowing. The pregnant sows were moved to farrowing pens, seven days to the expected date of farrowing. Three days after farrowing, the piglets were injected 2mls of iron injection intramuscularly (IM). Sows were fed lactation diet from entry into the farrowing pen until weaning. Piglets were offered creep feed from day 14 after farrowing. Clean and cool water was provided.

3.18 Data Collection

Collection of data started immediately after the sows farrowed and they were separated into their respective treatments and replicates, these include farrowing indices of the sows, growth performance, stress and behavioural indices for the piglets, performance and reproductive hormones for the sows.

3.18.1 Body Weight Gain, Feed Intake and Feed Conversion Ratio

Provision of feed was done two times per day at the hours of 08:00 and 14:00 daily. Quantity of feed served was weighed and fed to the pigs per replicate and the leftover feed was weighed using a table top weighing scale (Camry, 25 kg). The feed intake was calculated by deducting the leftover from the amount served as follows:

$$\text{Feed Intake} = \text{Amount of feed served} - \text{Amount of feed leftover} \qquad \ldots\ldots \quad 3.3$$

Pigs in each replicate were weighed at the commencement of the experiment and on weekly basis using weighing scale. At the termination of the experiment, the total weights gained were determined by deducting the initial body weight from the final body weight. Feed conversion ratio (FCR) was calculated as a ratio of feed consumed to the body weight change and it is expressed as;

$$\text{FRC} = \frac{\text{Average feed consumed}}{\text{Average weight gain}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad 3.4$$

3.18.2 Blood Collection, Haematology and Serum Biochemistry

On the first day of intermittent suckling, blood samples (5mls per sample) were collected from the piglets and sows, and subsequently on days 1, 4, 7, 11 and 14 for the piglets, and until oestrus was detected for the sows. The blood samples used for haematology were collected into bottles containing EDTA to prevent coagulation while the blood samples used for serum analysis were collected into plain bottles.

Serum corticosterone, luteinising hormone, follicle stimulating hormone and oestrogen were determined using commercially available ELISA kit (Enzo Life Sciences, Cortisol ELISA kit, AD-901-071, Farmingdale, NY) in accordance with the manufacturers' instruction.

The parameters determined for haematology were white blood cells, lymphocytes, monocytes, neutrophils and eosinophils as described by Schalm *et al.* (1975).

3.18.3 Behavioural Parameters

A total of sixteen Close circuit television (CCTV) were used in monitoring and recording the behaviour of the piglets in this experiment. Remote operation of camera control equipment and video recorder were placed in a room far away from the pens to ensure the pigs activities were not influenced by operator presence. The behavioural data are according to the ethogram in Table 3.1 and were deduced from the video recordings which includes feeding, biting pen mates, chasing pen mates, belly nosing pen mates and nosing pen mates. All these were counted to measure the feeding behaviour, aggressive behaviour, and manipulative behaviour. The counting from the video recordings was done for one minute at each ten minutes, making a total of 24 counts in the four hours of each recording; this is known as Instantaneous Scan Sampling. The frequency of occurrence of each group of observation on the ethogram was then expressed as a percentile of the total observation according to Scott *et al.,* (2006a, b).

3.19 Statistical Analysis

Performance and haematology data were analysed with one-way analysis of variance (ANOVA) using SAS (2010). Means were separated with New Duncan Multiple Range Test, while data on corticosterone, luteinising hormone, follicle stimulating hormone, oestrogen and behavioural response were analysed using descriptive statistics.

EXPERIMENT TWO: Duration of Intermittent Suckling on Weanling Pigs' Growth, Behaviour, Stress Response and Subsequent Reproductive Performance of the Dam

3.20 Specific Objective:

To evaluate the durations of intermittent suckling effect on weanling pigs growth, behaviour, stress response and subsequent reproductive performance of the dam

3.21 Site of Experiment

This experiment was carried out at the Piggery Unit of the Teaching and Research Farm, University of Ibadan, Nigeria. The farm is situated in South-western part of Nigeria on longitude 7.47491 and latitude 3.91371, at an altitude of 200-300m above the sea level. The average temperature ranges from 25 °C to 32 °C, humidity 71.53% to 76.00% and an annual rainfall of 1250mm to 1500mm which all characterise a tropical climate.

3.22 Experimental Animals

A total of sixteen sows and sixty-four weanling pigs (Largewhite X Landrace) were distributed into four treatments, with each having four replicates (one sow and four weanling pigs/replicate) arranged in a completely randomised design (CRD). Feeds and water were served two times per day between the hours of 08:00 and 14:00 throughout the six weeks of the experiment.

3.23 Experimental Ration

The animals used for this experiment were fed concentrates during the six weeks of the experiment. The gross composition of diet given to the weanling pigs and sows are as shown in Tables 3.3 and 3.4 respectively.

3.24 Experimental Layout and Design

The design of the experiment was completely randomised design. Pigs were allotted into four treatments which include:

Treatment 1: Continuous suckling

Treatment 2: Separation for 4 hours/day for 14 days

Treatment 3: Separation for 8 hours/day for 14 days

Treatment 4: Separation for 12 hours/day for 14 days

3.25 Management of Experimental Pigs

After experiment 1 i.e. when the piglets have been weaned, the sixteen sows and sixty-four weanling pigs were dewormed with Levamisole administered (based on their body weight), and Ivermectin (1.5 ml/50 kg body weight) against internal and external parasites respectively, antibiotics 20% L.A with multivitamins were also administered. The sows were mated as soon as they returned to oestrus. Mating date was recorded in order to know the expected date of farrowing. The pregnant sows were moved to farrowing pens, seven days to the expected date of farrowing.

3.26 Data Collection

Data were collected on growth performance, stress and behavioural indices of the weanling pigs (as described in experiment one), as well as performance and reproductive indices of the sows.

3.26.1 Reproductive Parameters

The reproductive parameters measured include weaning to oestrus interval, percentage conception, average litter size, average litter birth weight, average number of piglets born alive and average number of still births (Hines and Loucks, 2020).

3.27 Statistical Analysis

Performance data, reproductive data and haematology data were analysed with one-way analysis of variance (ANOVA) using SAS (2010) and means were separated with New Duncan Multiple Range Test while corticosterone data and behavioural data were analysed using descriptive statistics.

CHAPTER FOUR

RESULTS

4.1 Dam Reproductive Performance, Growth, Behavioural and Stress Responses of Weanling Pigs to Weaning Time

4.1.1 Reproductive Performance of the Sows

The reproductive performance of the sows was as presented in Table 4.1. In the result, no significant ($p>0.05$) difference was observed across the treatments for all the parameters. The three treatments had an average litter size and average number of piglets born alive of 6. The average litter birth weight ranged from 1.32±0.02 kg in T1(4 weeks) to 1.30±0.13 kg in T3 (8 weeks), while the average number of still births was 0.

4.1.2 Growth Performance of Weanling Pigs Weaned at Different Weaning Time

The growth performance of weanling pigs weaned at different weaning time was as shown in Table 4.2. There were significant ($p<0.05$) differences among the treatments for average weight gain, average feed intake, final weight and feed conversion ratio. The mean values for average feed intake showed that, T3 (8 weeks) (12.81±0.61 kg) and T2 (6 weeks) (12.70±0.39 kg) were significantly ($p<0.05$) higher than T1 ($ weeks) (10.94±0.48 kg). For average weight gain, T3 (8 weeks) (5.76±0.29 kg) and T2 (6 weeks) (5.69±0.36 kg) were significantly ($p<0.05$) higher than T1(4 weeks) (4.53±0.18 kg). Also, the mean values for the final weight showed that T3 (8 weeks) (11.78±0.31 kg) and T2 (6 weeks) (11.18±0.46 kg) were significantly ($p<0.05$) higher than T1 (4 weeks) (8.84±0.24 kg). The feed conversion ratio across the treatments were significantly ($p<0.05$) different, T1 (4 weeks) (2.42±0.09) was significantly ($p<0.05$) higher than T2 (6 weeks) (2.23±0.15) and T3 (8 weeks) (2.22±0.10).

Table 4.1: Reproductive Performance of the Sows

Parameters	Weaning time		
	4 weeks	6 weeks	8 weeks
Average litter size	6.00±0.43	6.00±1.09	6.00±0.83
Average litter birth weight (kg)	1.32±0.02	1.27±0.10	1.30±0.13
Average no. of piglets born alive	6.00±0.43	6.00±1.09	6.00±0.83
Average no. of still births	0.00±0.00	0.00±0.00	0.00±0.00

Table 4.2: Growth Performance of Weanling Pigs Weaned at Different Weaning Time

	Weaning time		
Parameters	4 weeks	6 weeks	8 weeks
Initial weight (Kg)	4.31±0.15	5.49±0.42	6.02±0.27
Average feed intake (Kg)	10.94±0.48[b]	12.70±0.39[a]	12.81±0.61[a]
Average weight gain (kg)	4.53±0.18[b]	5.69±0.36[a]	5.76±0.29[a]
Final weight (Kg)	8.84±0.24[b]	11.18±0.46[a]	11.78±0.31[a]
Feed conversion ratio	2.42±0.09[a]	2.23±0.15[b]	2.22±0.10[b]

[a, b] Means in the same row with different superscripts are significantly different ($p<0.05$)

4.1.3 Corticosterone Concentration in Weanling Pigs Weaned at Different Weaning Time

Shown on Figure 4.1 was the result of the corticosterone concentration (ng/ml) in weanling pigs weaned at different weaning time. Animals in T1(4 weeks) were more stressed after weaning compared to T2 (6 weeks) and T3 (8 weeks). The corticosterone concentration for T1 (4 weeks) was highest on day 4 (55.83 ng/ml) compared to T2 (6 weeks) and T3 (8 weeks) which were 48.6 ng/ml and 48.31 ng/ml, respectively.

4.1.4 White Blood Cell Counts of Weanling Pigs Weaned at Different Weaning Time

Shown on Table 4.3 was the result of white blood cell count ($X10^3$ µl) of weanling pigs weaned at different weaning time. No significant ($p<0.05$) difference was observed among the treatments from day 1 to 14. On day 1, white blood cells in animals in T1 (4 weeks) (8.83±0.07) was significantly ($p<0.05$) higher than T2 (6 weeks) (8.53±0.12) and T3 (8 weeks) (8.62±0.14). The values obtained for days 4. 7, 11 and 14 followed the same trend.

4.1.5 Lymphocyte Counts of Weanling Pigs Weaned at Different Weaning Time

Presented on Table 4.4 was the lymphocyte count (%) of weanling pigs weaned at different weaning time. No significant ($p>0.05$) difference was observed among the treatments from day 1 to 14.

4.1.6 Neutrophil Counts of Weanling Pigs Weaned at Different Weaning Time

Presented on Table 4.5 was the neutrophil count (%) of weanling pigs weaned at different weaning time. There was no significant ($p>0.05$) difference among the treatments from days 1 to 14.

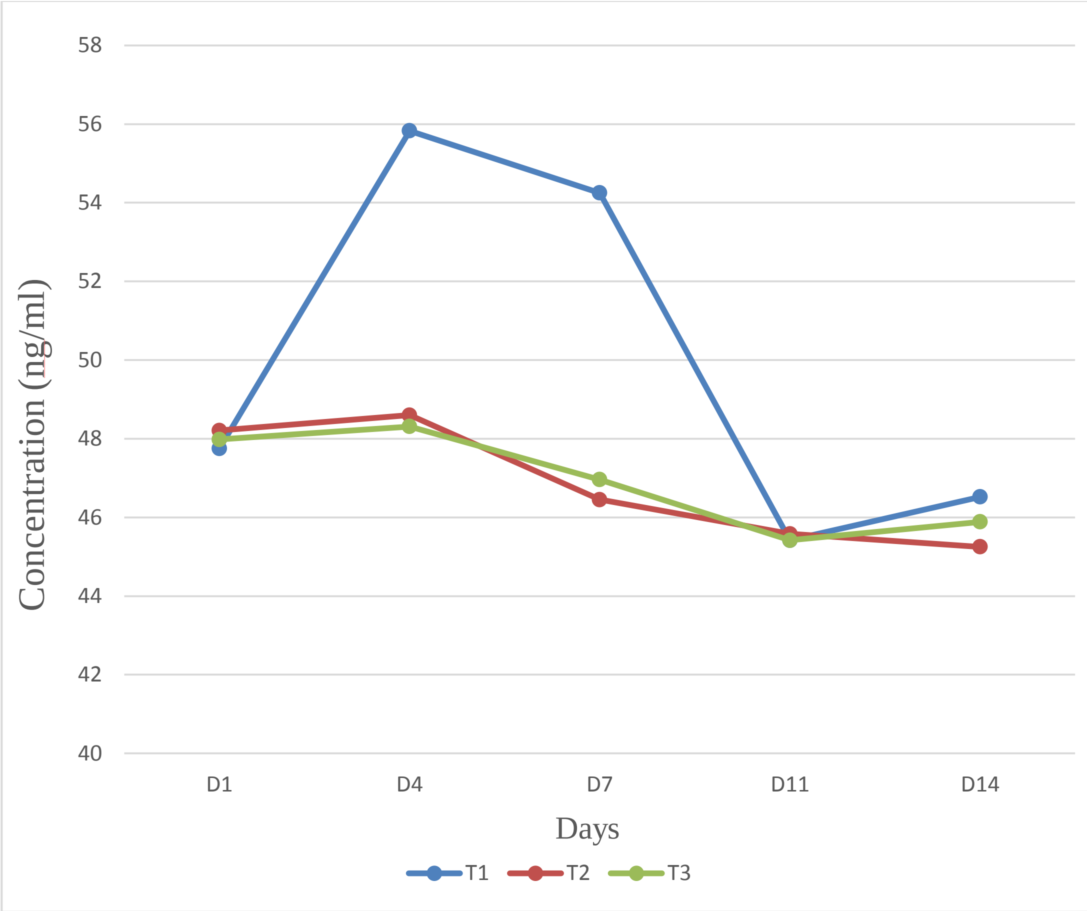

Figure 4.1: Corticosterone Concentration (ng/ml) in Weanling Pigs Weaned at Different Weaning Time

Treatment 1: Weaning at 4 weeks

Treatment 2: Weaning at 6 weeks

Treatment 3: Weaning at 8 weeks

Table 4.3: White Blood Cell Counts ($X10^3$ µl) of Weanling Pigs Weaned at Different Weaning Time

Day	Weaning time		
	4 weeks	6 weeks	8 weeks
1	$8.83±0.07^a$	$8.53±0.12^b$	$8.62±0.14^b$
4	$11.08±0.15^a$	$9.80±0.23^b$	$9.10±0.08^c$
7	$9.98±0.15^a$	$9.20±0.21^b$	$8.98±0.05^b$
11	$9.69±0.12^a$	$8.78±0.10^b$	$8.64±0.16^b$
14	$8.71±0.11^a$	$8.49±0.20^b$	$8.53±0.09^b$

$^{a, b, c}$ Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4.4: Lymphocyte Counts (%) of Weanling Pigs Weaned at Different Weaning Time

	Weaning time		
Day	4 weeks	6 weeks	8 weeks
1	44.33±0.23	45.00±0.27	43.33±0.17
4	40.33±0.41	42.00±0.21	42.67±0.52
7	41.67±0.30	43.67±0.42	43.33±0.19
11	43.67±0.33	44.33±0.25	44.33±0.42
14	43.67±0.36	44.00±0.14	45.00±0.34

Table 4.5: Neutrophil Counts (%) of Weanling Pigs Weaned at Different Weaning Time

Day	Weaning time		
	4 weeks	6 weeks	8 weeks
1	48.00±0.91	48.00±0.46	49.33±0.67
4	52.67±0.74	50.33±0.54	50.00±0.16
7	50.67±0.61	49.00±0.53	48.67±0.46
11	49.33±0.57	48.67±0.42	48.33±0.59
14	49.67±0.83	49.00±0.34	48.00±0.69

4.1.7 Monocyte Counts of Weanling Pigs Weaned at Different Weaning Time

Presented on Table 4.6 was the monocyte counts (%) of weanling pigs weaned at different weaning time. There was no significant (p>0.05) difference in the monocyte counts among the treatments from days 1 to 7. However, there were significant (p<0.05) differences among the treatments from days 11 to 14. On day 11, monocytes in animals in T3 (8 weeks) (3.92±0.14%) was significantly (p<0.05) higher than T2 (6 weeks) (3.17±0.15%) and T1 (4 weeks) (3.50±0.24%). Also, on day 14, monocytes in animals in T3 (8 weeks) (3.58±0.26%) was significantly (p<0.05) higher than T2 (6 weeks) (2.58±0.16%) but not significantly (p>0.05) different from T1 (4 weeks) (3.34±0.07).

4.1.8 Eosinophil Counts of Weanling Pigs Weaned at Different Weaning Time

Presented on Table 4.7 was the eosinophil count (%) of weanling pigs weaned at different weaning time. There was no significant (p>0.05) difference in eosinophil counts among the treatments from days 4 to 14. However, there were significant (p<0.05) differences among the treatments for day 1, T1 (4 weeks) (4.75±0.04 %) was significantly (p<0.05) higher than T2 (6 weeks) (3.75±0.13 %) and T3 (8 weeks) (3.88±0.10 %).

4.1.9 Feeding Behaviour of Weanling Pigs Weaned at Different Weaning Time

Presented on Figure 4.2 was the feeding behaviour of weanling pigs weaned at different weaning time. Pigs weaned at age of 4 weeks spent lesser time feeding than those weaned at 6 and 8 weeks. T1 (4 weeks) had the lowest value on day 1 (41.72 %), while the highest value was on day 10 (60.2 %). T2 (6 weeks) had the lowest value on day 2 (58.10 %), while the highest value was on day 10 (70.3 %). T3 (8 weeks) had the lowest value on day 1 (63 %), while the highest value was on day 10 (70.31 %).

Table 4.6: Monocyte Counts (%) of Weanling Pigs Weaned at Different Weaning Time

Day	Weaning time		
	4 weeks	6 weeks	8 weeks
1	3.75±0.03	3.00±0.21	2.96±0.07
4	3.42±0.13	3.50±0.24	3.42±0.14
7	3.08±0.12	3.67±0.17	3.75±0.20
11	3.50±0.24^{b}	3.17±0.15^{b}	3.92±0.14^{a}
14	3.34±0.07^{ab}	2.58±0.16^{b}	3.58±0.26^{a}

$^{a,\ b}$ Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4.7: Eosinophil Counts (%) of Weanling Pigs Weaned at Different Weaning Time

	Weaning time		
Day	4 weeks	6 weeks	8 weeks
1	4.75±0.04[a]	3.75±0.13[b]	3.88±0.10[b]
4	3.92±0.08	3.67±0.05	3.84±0.14
7	3.58±0.21	3.83±0.06	4.50±0.17
11	3.34±0.06	3.75±0.13	4.25±0.24
14	3.67±0.08	3.83±0.16	3.25±0.14

[a, b] Means in the same row with different superscripts are significantly different ($p<0.05$)

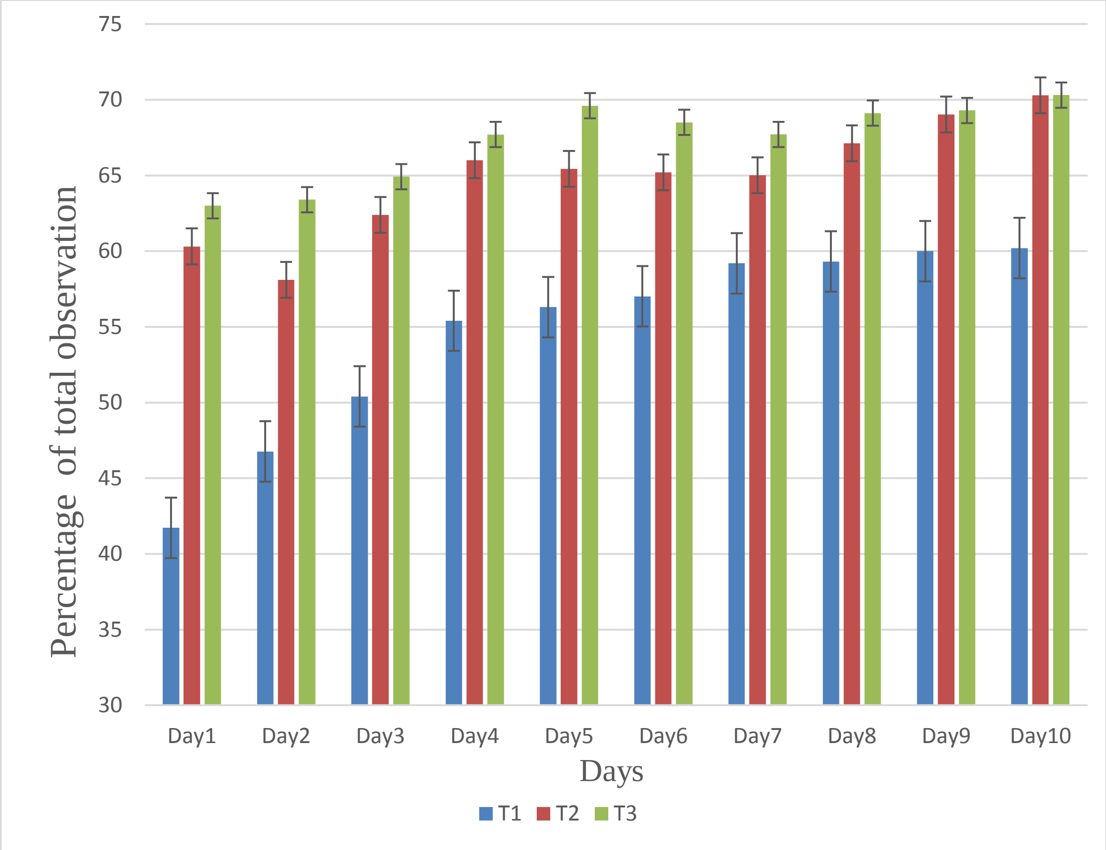

Figure 4.2: Feeding Behaviour of Weanling Pigs Weaned at Different Weaning Time

Treatment 1: Weaning at 4 weeks

Treatment 2: Weaning at 6 weeks

Treatment 3: Weaning at 8 weeks

4.1.10 Aggressive Behaviour of Weanling Pigs Weaned at Different Weaning Time

Presented on Figure 4.3 was the aggressive behaviour of weanling pigs weaned at different weaning time. Pigs weaned at age of 4 weeks were more aggressive in the first 3 days than those weaned at 6 and 8 weeks. T1 (4 weeks) had the highest value on day 1 (9.24 %), while the lowest value was on day 10 (0.52 %). T2 (6 weeks) had the highest value on day 2 (6.34 %), while the lowest value was on day 9 (1.06 %). T3 (8 weeks) had the highest value on day 1 (4.16 %), while the lowest value was on day 6 (0.52 %).

4.1.11 Manipulative Behaviour of Weanling Pigs Weaned at Different Weaning Time

Presented on figure 4.4 was the manipulative behaviour of weanling pigs weaned at different weaning time. Pigs weaned at age of 4 weeks showed higher interaction with their pen and pen mates for the first 6 days compared to those weaned at 6 and 8 weeks. T1 (4 weeks) had the highest value on day 1 (8.28 %), while the lowest value was on day 10 (0.52 %). T2 (6 weeks) had the highest value on day 1 (5.83 %), while the lowest value was on day 10 (0.51 %). T3 (8 weeks) had the highest value on day 1 (3.66 %), while the lowest value was on day 6, 8 and 10 (0.52 %).

4.1.12 Growth Performance of Lactating Sows with Piglets Weaned at Different Weaning Time

The growth performance of lactating sows with piglets weaned at different weaning time was as shown in Table 4.8. There were no significant ($p>0.05$) differences among the treatments for initial body weight which ranged from 55.00±1.41 kg in T1 (4 weeks) to 50.00±2.24 kg in T3 (8 weeks), and average feed intake that ranged from 27.81±0.64 kg in T1 (4 weeks) to 27.19±0.16 kg in T3 (8 weeks). However, there were significant ($p<0.05$) differences among the treatments for average weight gain and final weight. The mean values for average weight gain showed that, T1 (4 weeks) (-5.00±1.41 kg) was significantly ($p<0.05$) higher than T2 (6 weeks) (-6.25±0.33 kg) and T3 (8 weeks) (-10.00±1.58 kg). Also, the mean values for the final weight showed that T1 (4 weeks) (50.00±1.41 kg) was significantly ($p<0.05$) higher than T2 (6 weeks) (45.50±0.53 kg) and T3 (8 weeks) (40.00±2.55 kg).

4.1.13 Reproductive Performance of Sows Weaned at Different Weaning Time

The reproductive performance of sows weaned at different weaning time was as shown in Table 4.9. There were no significant ($p>0.05$) differences among the treatments for the percentage conception which ranged from 100.00 % in T1 (4 weeks) and T2 (6 weeks) to 83.33 % in T3 (8 weeks), number of still-births which was 0.00 for all the treatments, and average litter birth weight which ranged from 1.38±0.14 kg in T1 (4 weeks) to 1.30±0.19 kg in T3 (8 weeks). However, weaning to oestrus interval, average litter size and number of piglets born alive were significantly ($p<0.05$) different among the treatments. The mean values for weaning to oestrus interval showed that, T3 (8 weeks) (10.00±1.58 days) was significantly ($p<0.05$) higher than T2 (6 weeks) (7.00±1.22 days) and T1 (4 weeks) (6.00±0.71 days). Also the mean values for average litter size and number of piglets born alive showed that T1 (4 weeks) (8.00±0.71) and T2 (6 weeks) (7.00±1.58) were significantly ($p<0.05$) higher than T3 (8 weeks) (5.00±1.22).

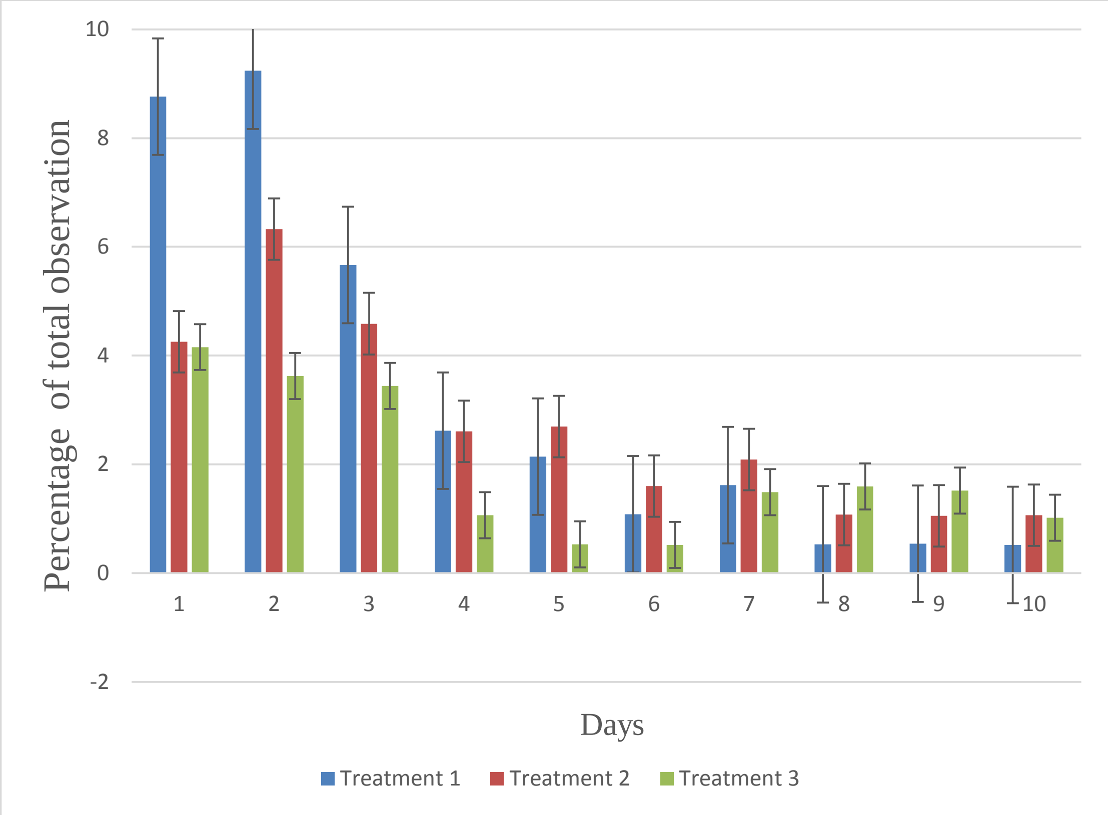

Figure 4.3: Aggressive Behaviour of Weanling Pigs Weaned at Different Weaning Time

Treatment 1: Weaning at 4 weeks

Treatment 2: Weaning at 6 weeks

Treatment 3: Weaning at 8 weeks

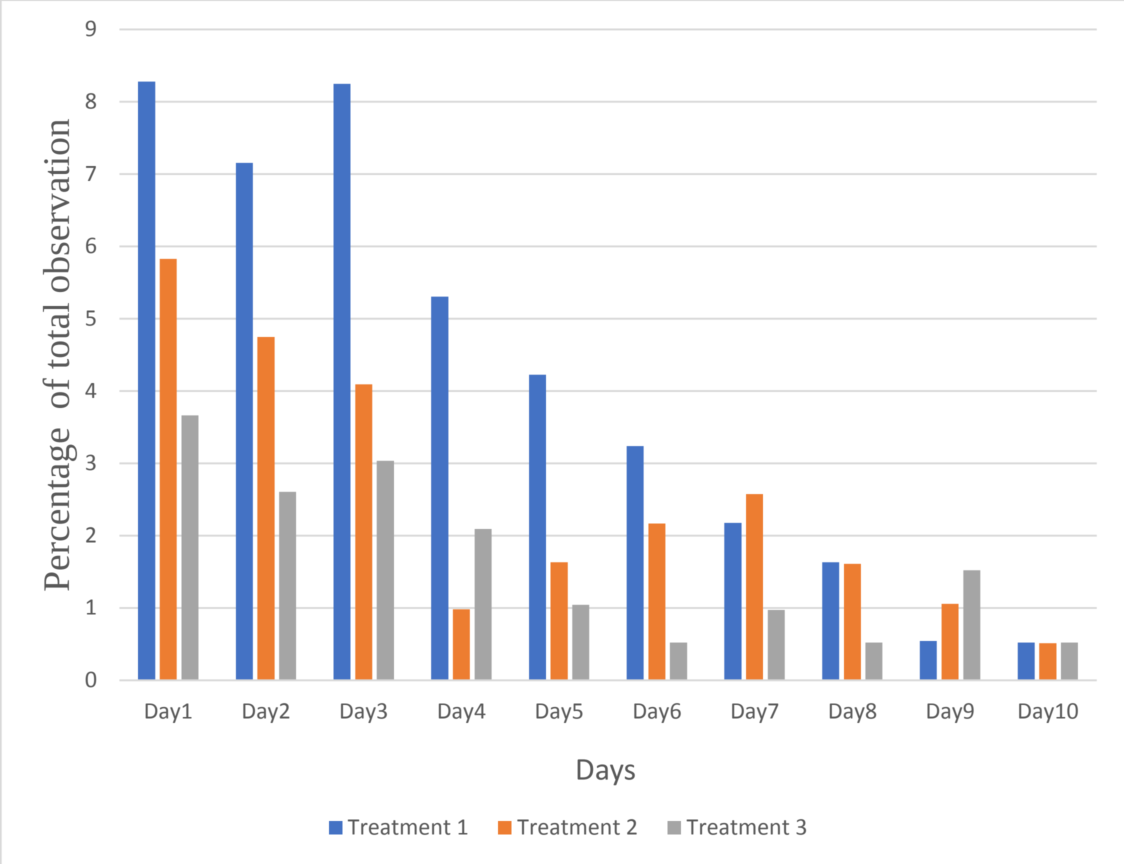

Figure 4.4: Manipulative Behaviour of Weanling Pigs Weaned at Different Weaning Time

Treatment 1: Weaning at 4 weeks

Treatment 2: Weaning at 6 weeks

Treatment 3: Weaning at 8 weeks

Table 4.8: Growth Performance of Lactating Sows with Piglets Weaned at Different Weaning Time

	Weaning time		
Parameters (Kg)	4 weeks	6 weeks	8 weeks
Initial weight	55.00±1.41	51.75±0.53	50.00±2.24
Average feed intake	27.81±0.64	27.29±0.38	27.19±0.16
Average weight change	-5.00±1.41[a]	-6.25±0.33[b]	-10.00±1.58[b]
Final weight	50.00±1.41[a]	45.50±0.53[b]	40.00±2.55[c]

[a, b, c] Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4.9: Reproductive Performance of Sows Weaned at Different Weaning Time

Parameters	Weaning time		
	4 weeks	6 weeks	8 weeks
Weaning to oestrus interval (days)	6.00±0.71[b]	7.00±1.22[b]	10.00±1.58[a]
Percentage conception (%)	100.00	100.00	83.33
Average litter size	8.00±0.71[a]	7.00±1.58[a]	5.00±1.22[b]
Number of piglets born alive	8.00±0.71[a]	7.00±1.58[a]	5.00±1.22[b]
Number of still births	0.00±0.00	0.00±0.00	0.00±0.00
Average litter birth weight (Kg)	1.38±0.14	1.33±0.27	1.30±0.19

[a, b] Means in the same row with different superscripts are significantly different ($p<0.05$)

4.2 Duration of Intermittent Suckling on Piglets' Growth, Behaviour, Stress Response and Subsequent Reproductive Performance of the Dam

4.2.1 Growth Performance of Piglets before and during Intermittent Suckling

The growth performance of piglets before and during intermittent suckling was as shown in Table 4.10. There was no significant (p>0.05) differences among the treatments for initial weight which ranged from 1.36 ±0.13 kg in T1 (0 hours) to 1.30 ±0.17 kg in T2 (4 hours), and average weight gain (AWG) week 2 which ranged from 0.65 ±0.15 kg in T1 (0 hours) to 0.62 ±0.21 kg in T3 (8 hours). However, there were significant (p<0.05) differences among the treatments for AWG (for weeks 1, 3, 4, 5 and 6), final weight, average weight gain, and creep feed intake. The mean values for final weight showed that, T1 (0 hours) (6.22 ±0.26 kg) was significantly (p<0.05) higher than T2 (4 hours) (5.59 ±0.38 kg), T3 (8 hours) (5.51 ±0.21 kg), and T4 12 hours) (5.47 ±0.40 kg). The mean values for average weight gain followed the same trend as seen in final weight. T1 (0 hours) (4.86 ±0.30 kg) was significantly (p<0.05) higher than T2 (4 hours) (4.29 ±0.28 kg), T3 (8 hours) (4.17 ±0.15 kg), and T4 (hours) (4.14 ±0.19 kg). Also, the mean values for the creep feed intake showed that T4 (12 hours) (2.50 ±0.31 kg) and T3 (8 hours) (2.20 ±0.33 kg) were significantly (p<0.05) higher than T2 (4 hours) (1.70 ±0.24 kg) and T1 (0 hours) (0.90 ±0.15 kg).

4.2.2 Corticosterone Concentration in Piglets during Intermittent Suckling

Shown on Figure 4.5 was the result of the corticosterone concentration (ng/ml) in piglets during intermittent suckling. Animals in T4 (12 hours) were more stressed after weaning compared to T2 (4 hours) and T3 (8 hours), piglets in T1 (0 hours) were relatively stable. The corticosterone concentration for T4 (12 hours) was the highest on day 4 (59.43 ng/ml) compared to T2 (4 hours), T3 (8 hours) and T1 (0 hours) which were 57.44 ng/ml, 57.74 ng/ml, and 43.86 ng/ml, respectively.

4.2.3 White Blood Cell Counts of Piglets during Intermittent Suckling

Shown on Table 4.11 was the result of white blood cell count ($\times 10^3$ µl) of piglets during intermittent suckling. There was no significant (p>0.05) difference among the treatments for day 1. The mean values ranged from 9.25±0.64 in T2 (4 hours) to 9.46±0.48 in T3 (8 hours). However, there were significant (p<0.05) differences among the treatments from day 4 to 14. On day 4, white blood cells in animals in T4 (12 hours) (11.90±0.14 $\times10^3$ µl) was significantly ($p<0.05$) higher than T3 (8 hours) (11.42±0.34 $\times10^3$ µl), T2 (4 hours) (11.08±0.96 $\times10^3$ µl) and T1 (0 hours) (9.27±0.13 $\times10^3$ µl). The values obtained for day 7 followed the same trend as seen on day 4. The white blood cells in animals in T4 (12 hours) (10.62±0.53 $\times10^3$µl) was significantly ($p<0.05$) higher than T3 (8 hours) (10.38±0.45 $\times10^3$ µl), T2 (4 hours) (10.08±0.43 $\times10^3$ µl) and T1 (0 hours) (9.41±0.08 $\times10^3$ µl). On day 11, white blood cells in animals in T4 (12 hours) (10.46±0.84 $\times10^3$ µl) was significantly ($p<0.05$) higher than T3 (8 hours) (9.95±0.37 $\times10^3$ µl), T2 (4 hours) (9.87±0.42 $\times10^3$ µl) and T1 (0 hours) (9.28±0.17 $\times10^3$µl). On day 14, the white blood cells in animals in T4 (12 hours) (9.75±0.84 $\times10^3$µl) and T3 (8 hours) (9.61±0.23 $\times10^3$ µl) were significantly ($p<0.05$) higher than T1 (0 hours) (9.37±0.16 $\times10^3$µl).

4.2.4 Lymphocyte Counts of Piglets during Intermittent Suckling

Presented on Table 4.12 was the result of lymphocyte (%) in piglets during intermittent suckling. There was no significant ($p>0.05$) difference among the treatments for day 1 and 14. The mean values for day 1 ranged from 47.50±0.13 in T3 (8 hours) to 46.00±0.25 in T4 (12 hours), while the mean values for day 14 ranged from 47.00±0.35 in T1 (0 hours) to 45.50±0.14 in T4 (12 hours). However, there were significant ($p<0.05$) differences among the treatments from days 4 to 11. On day 4, lymphocytes in animals in T1 (0 hours) (47.75±0.14 %) was significantly ($p<0.05$) higher than T4 (12 hours) (42.00±0.14 %). On day 7, lymphocytes in animals in T1 (0 hours) (46.50±0.47 %) was significantly ($p<0.05$) higher than T3 (8 hours) (43.00±0.19 %) and T4 (12 hours) (42.25±0.08 %). Also, on day 11, lymphocytes in animals in T1 (0 hours) (46.50±0.29 %) and T2 (4 hours) (45.50±0.42 %) were significantly ($p<0.05$) higher than T4 (12 hours) (43.75±0.16 %).

4.2.5 Neutrophil Counts of Piglets during Intermittent Suckling

The neutrophil counts (%) of piglets during intermittent suckling was shown on Table 4.13. No significant ($p>0.05$) difference was observed among the treatments for days 1 and 14. The mean values for day 1 ranged from 47.75±0.52 in T1 (0 hours) and T4 (12 hours) to 46.75±0.22 in T2 (4 hours) while the mean values for day 14 ranged from 48.50±0.62 in T3 (8 hours) to 47.25±0.30 at T1 (0 hours) and T2 (4 hours). However, there were significant ($p<0.05$) differences among the treatments from day 4 to 11. On day 4, neutrophils in animals in T4 (12 hours) (52.00±0.63 %) was significantly ($p<0.05$) higher than T1 (0 hours) (46.25±0.21 %). On day 7, neutrophils in animals in T4 (12 hours) (50.75±0.33 %) and T3 (8 hours) (50.75±0.19 %) were significantly ($p<0.05$) higher than T1 (0 hours) (47.00±0.25 %). Also, on day 11, neutrophils in animals in T4 (12 hours) (49.50±0.30 %) and T3 (8 hours) (49.25±0.14 %) were significantly ($p<0.05$) higher than T1 (0 hours) (47.50±0.21 %).

4.2.6 Monocyte Counts of Piglets during Intermittent Suckling

The monocyte counts (%) of piglets during intermittent suckling was shown on Table 4.14. There was no significant ($p>0.05$) difference among the treatments from days 1 to 14.

4.2.7 Eosinophil Counts of Piglets during Intermittent Suckling

The eosinophil counts (%) of piglets during intermittent suckling was shown on Table 4.15. There was no significant ($p>0.05$) difference among the treatments from days 1 to 14.

4.2.8 Feeding Behaviour of Piglets during Intermittent Suckling

Presented on Figure 4.6 was the feeding behaviour of piglets during intermittent suckling. The piglets on T1 (0 hours) spent more time feeding for the first five days than those separated from the sow for 4, 8, and 12 hours. T1 (0 hours) had the lowest value on day 1 and 3 (25.75 %), while the highest value was on day 7 (34.5 %). The T2 (4 hours) had the lowest value on day 1 (8.95 %), while the highest value was on day 10 (39.2 %). The T3 (8 hours) had the lowest value on day 1 (9.75 %), while the highest value was on day 10 (41.25 %). The T4 (12 hours) had the lowest value on day 1 (8.5 %), while the highest value was on day 10 (45.1 %).

4.2.9 Aggressive Behaviour of Piglets during Intermittent Suckling

Presented on Figure 4.7 was the aggressive behaviour of piglets during intermittent suckling. The piglets on T1 (0 hours) were less aggressive than those separated from the sow for 4, 8, and 12 hours. The T1 (0 hours) had the lowest value on days 2, 3, 4, 7, 8 and 9 (0 %), while the highest value was on day 6 (1.25 %). The T2 (4 hours) had the lowest value on day 10 (0.5 %), while the highest value was on day 1 (12.25 %). The T3 (8 hours) had the lowest value on day 9 (0 %), while the highest value was on day 1 (11.5 %). The T4 (12 hours) had the lowest value on day 10 (0 %), while the highest value was on day 1 (12.75 %).

4.2.10 Manipulative Behaviour of Piglets during Intermittent Suckling

Presented on Figure 4.8 was the manipulative behaviour of piglets during intermittent suckling. The T1 (0 hours) had the lowest value on day 10 (5.45 %), while the highest value was on day 8 (8.25 %). The T2 (4 hours) had the lowest value on day 8 (6.6 %), while the highest value was on day 5 (9.63 %). The T3 (8 hours) had the lowest value on day 7 (5.54 %), while the highest value was on day 1 (10.65 %). The T4 (12 hours) had the lowest value on day 6 (4.38 %), while the highest value was on day 5 (9.43 %).

4.2.11 Growth Performance of Lactating Sows Subjected to Different Durations of Separation from the Piglets

The growth performance of lactating sows subjected to different durations of separations from the piglets was as shown in Table 4.16. There were no significant ($p>0.05$) differences among the treatments for initial body weight which ranged from 63.67±1.89 kg in T2 (4 hours) to 60.33±1.41 kg in T4 (12 hours), average feed intake ranged from 30.67±2.28 kg in T1 (0 hours) to 28.92±2.02 kg in T3 (8 hours), and final weight ranged from 58.81±2.96 kg in T2 (4 hours) to 57.12±3.30 kg in T4 (12 hours). However, average weight loss was significantly ($p<0.05$) different among the treatments. The mean values showed that, T1 (0 hours) (-5.07±0.70 kg) and T2 (4 hours) (-4.86±0.46 kg) were significantly ($p<0.05$) different from T3 (8 hours) (-3.58±0.51 kg) and T4 (12 hours) (-3.21±0.60 kg).

Table 4.10: Growth Performance of Piglets before and during Intermittent Suckling

Parameters (Kg)	Hours of separation			
	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
Initial weight	1.36 ±0.13	1.30 ±0.17	1.34 ±0.26	1.33 ±0.15
AWG Week 1	0.72 ±0.21[a]	0.65 ±0.18[b]	0.64 ±0.26[b]	0.76 ±0.16[a]
AWG Week 2	0.65 ±0.15	0.62 ±0.23	0.62 ±0.21	0.63 ±0.24
AWG Week 3	0.78 ±0.22[a]	0.71 ±0.18[a]	0.62 ±0.24[b]	0.71 ±0.20[a]
AWG Week 4	0.79 ±0.17[a]	0.62 ±0.21[b]	0.75 ±0.25[a]	0.66 ±0.13[b]
AWG Week 5 (IS)	0.96 ±0.14[a]	0.82 ±0.16[b]	0.71 ±0.22[c]	0.60 ±0.21[d]
AWG Week 6 (IS)	0.96 ±0.20[a]	0.87 ±0.14[b]	0.83 ±0.24[b]	0.78 ±0.15[c]
Final weight	6.22 ±0.26[a]	5.59 ±0.38[b]	5.51 ±0.21[b]	5.47 ±0.40[b]
Average weight gain	4.86 ±0.30[a]	4.29 ±0.28[b]	4.17 ±0.15[b]	4.14 ±0.19[b]
Creep feed intake	0.90 ±0.15[c]	1.70 ±0.24[b]	2.20 ±0.33[a]	2.50 ±0.31[a]

[a, b, c, d] Means in the same row with different superscripts are significantly different ($p<0.05$)

AWG- Average Weight gain

IS- Intermittent Suckling

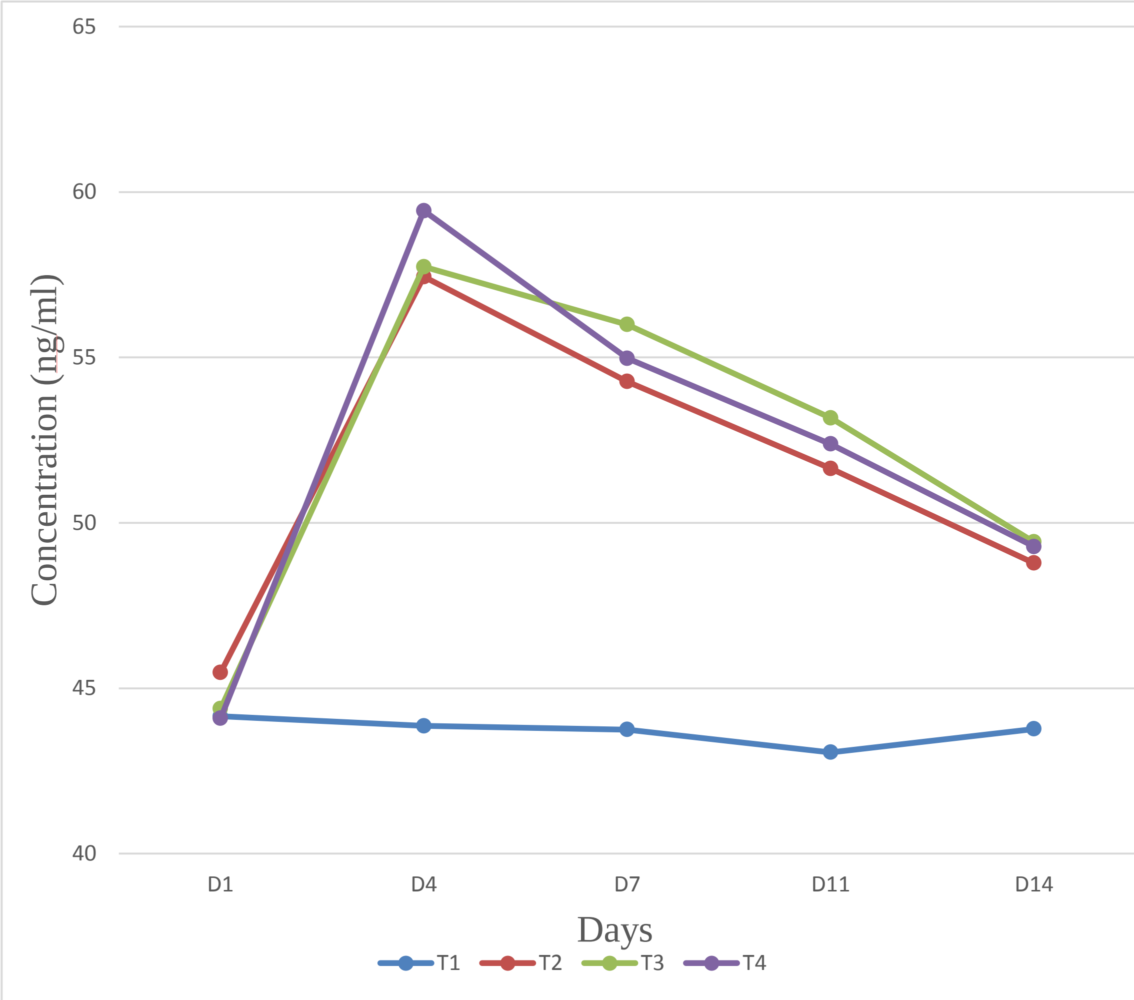

Figure 4.5: Corticosterone Concentration (ng/ml) in Piglets during Intermittent Suckling

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

Table 4.11: White Blood Cell Counts ($X10^3$ μl) of Piglets during Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	9.38±0.41	9.25±0.64	9.46±0.48	9.31±0.52
4	9.27±0.13^{d}	11.08±0.96^{c}	11.42±0.34^{b}	11.90±0.14^{a}
7	9.41±0.08^{d}	10.08±0.34^{c}	10.38±0.45^{b}	10.62±0.53^{a}
11	9.28±0.17^{c}	9.87±0.42^{b}	9.95±0.37^{b}	10.46±0.84^{a}
14	9.37±0.16^{b}	9.53±0.05^{ab}	9.61±0.23^{a}	9.75±0.60^{a}

$^{a, b, c, d}$ Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4.12: Lymphocyte Counts (%) of Piglets during Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	47.25±0.21	47.25±0.16	47.50±0.13	46.00±0.25
4	47.75±0.14[a]	44.00±0.32[ab]	43.25±0.20[ab]	42.00±0.14[b]
7	46.50±0.47[a]	44.75±0.25[ab]	43.00±0.19[b]	42.25±0.08[b]
11	46.50±0.29[a]	45.50±0.42[a]	44.50±0.31[ab]	43.75±0.16[b]
14	47.00±0.35	46.75±0.12	46.00±0.30	45.50±0.14

[a, b] Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4.13: Neutrophil Counts (%) of Piglets during Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	47.75±0.52	46.75±0.22	47.00±0.71	47.75±0.09
4	46.25±0.21^{b}	49.50±0.34^{ab}	50.50±0.41^{ab}	52.00±0.63^{a}
7	47.00±0.25^{b}	48.25±0.34^{ab}	50.75±0.19^{a}	50.75±0.33^{a}
11	47.50±0.21^{b}	48.25±0.47^{ab}	49.25±0.14^{a}	49.50±0.30^{a}
14	47.25±0.92	47.25±0.30	48.50±0.62	48.00±0.37

$^{a, b}$ Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4.14: Monocyte Counts (%) of Piglets during Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	2.50±0.03	3.00±0.20	2.50±0.06	3.00±0.15
4	3.00±0.03	3.50±0.14	3.00±0.17	3.00±0.10
7	3.50±0.16	3.50±0.10	3.25±0.02	3.75±0.22
11	3.00±0.15	3.25±0.05	2.75±0.24	3.00±0.14
14	2.75±0.03	3.00±0.14	2.50±0.08	2.75±0.16

Table 4.15: Eosinophil Counts (%) of Piglets during Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	2.50±0.13	3.00±0.24	3.00±0.02	3.25±0.05
4	3.00±0.20	3.00±0.13	3.25±0.05	3.00±0.02
7	3.00±0.09	3.50±0.14	3.00±0.10	3.25±0.16
11	3.00±0.06	3.00±0.17	3.50±0.23	3.75±0.12
14	3.00±0.17	3.00±0.07	3.00±0.16	3.75±0.21

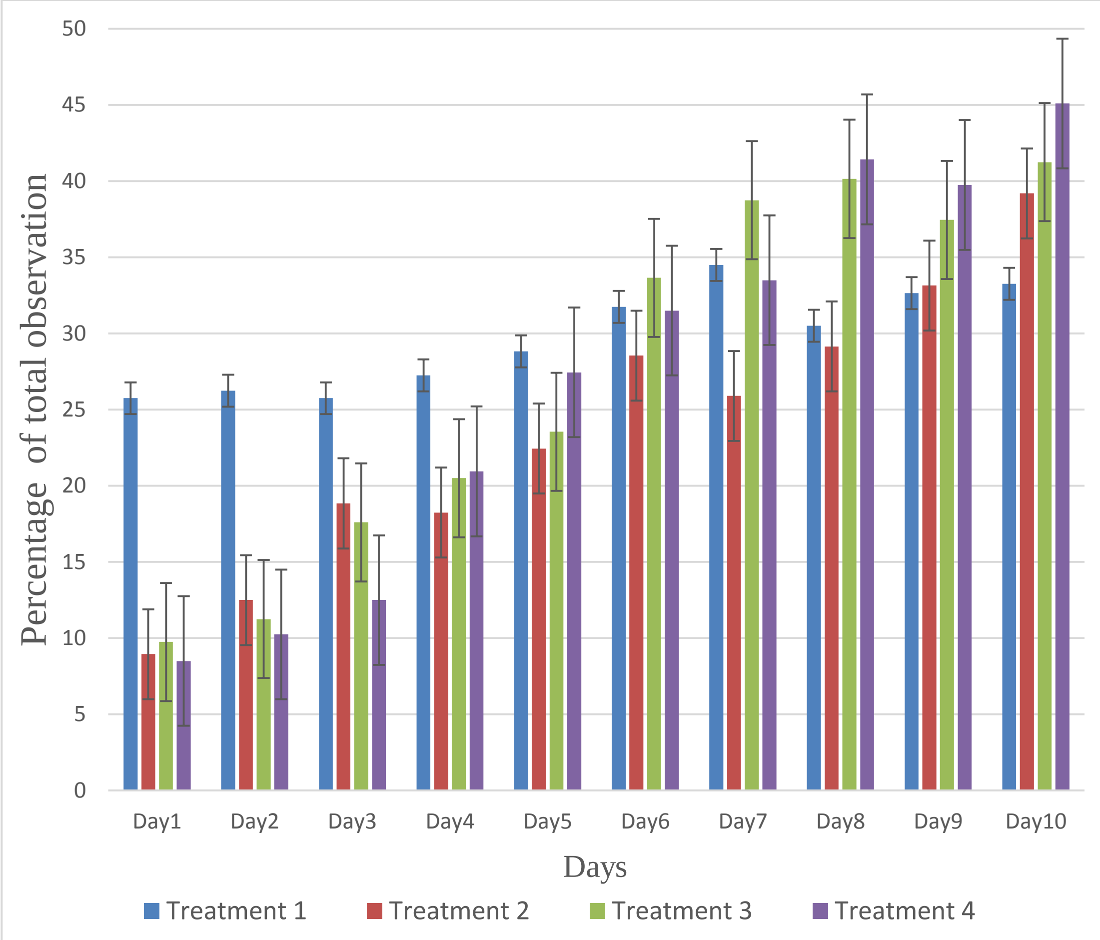

Figure 4.6: Feeding Behaviour of Piglets during Intermittent Suckling

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

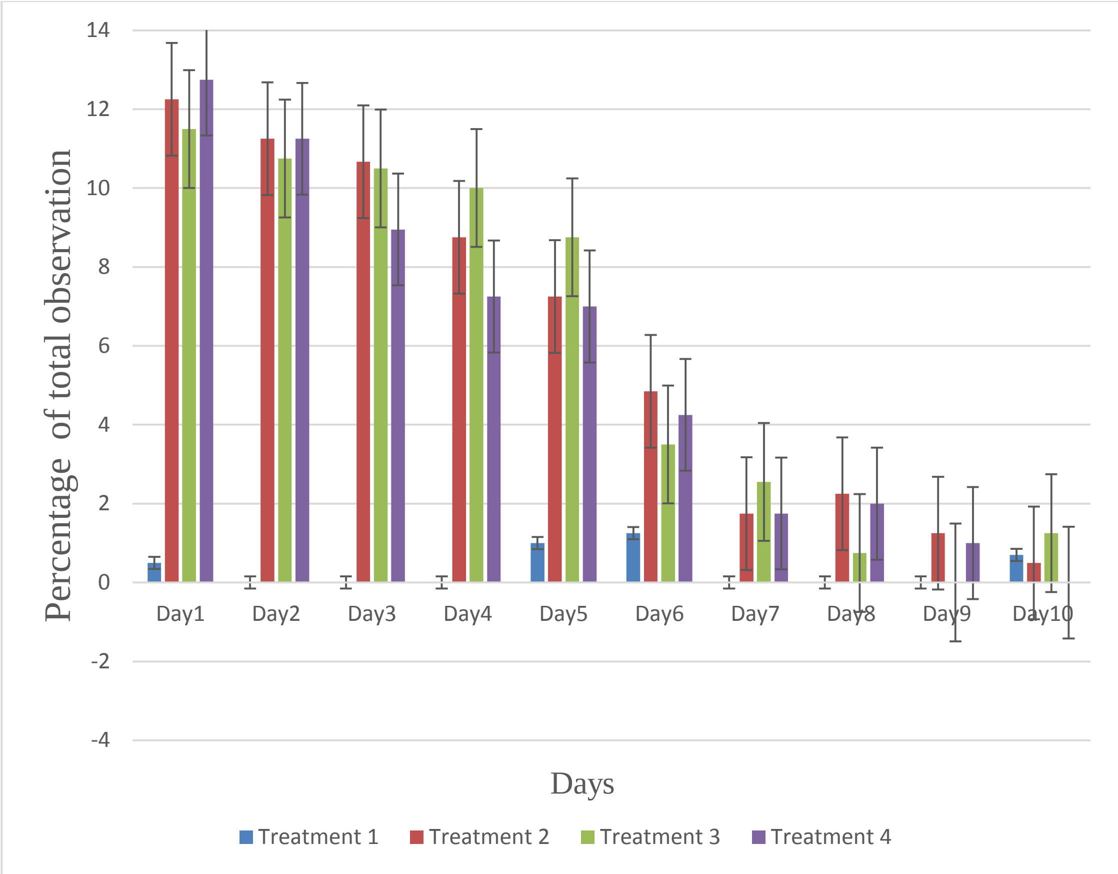

Figure 4.7: Aggressive Behaviour of Piglets during Intermittent Suckling

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

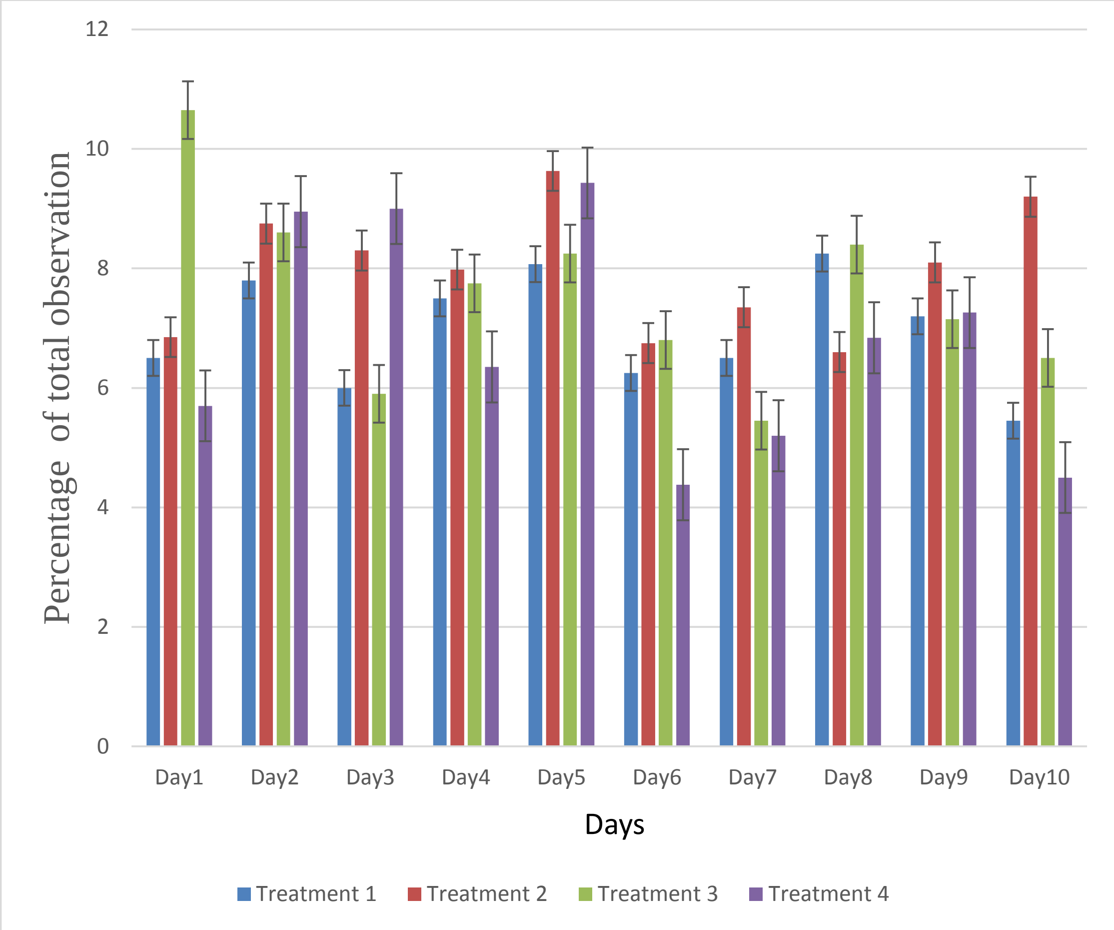

Figure 4.8: Manipulative Behaviour of Piglets during Intermittent Suckling

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

Table 4.16: Growth Performance of Lactating Sows Subjected to Different Durations of Separation from the Piglets

Parameters (Kg)	Hours of separation			
	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
Initial weight	63.00±3.35	63.67±1.89	61.00±2.55	60.33±1.41
Final weight	57.93±4.21	58.81±2.96	57.42±3.18	57.12±3.30
Average weight loss	-5.07±0.70^{a}	-4.86±0.46^{a}	-3.58±0.51^{b}	-3.21±0.60^{b}
Average feed intake	30.67±2.28	29.67±2.36	28.92±2.02	29.06±2.47

$^{a, b}$ Means in the same row with different superscripts are significantly different ($p<0.05$)

4.2.12 Luteinizing Hormone (LH) Concentration in Sows from the Period of Intermittent Suckling to the Onset of Oestrus

Shown in Figure 4.9 was the result of the luteinising hormone (LH) concentration (ng/ml) in sows from the period of intermittent suckling to onset of oestrus. There was a gradual increase in the LH concentration of the sows until there was a sharp increase which signified the peak of LH concentration. The mean value for LH concentration for sows in T1 (0 hours) was 1.24±0.03 ng/ml on day 1, while it peaked at 7.48±0.15 ng/ml on day 24. The sows in T2 (4 hours) had a mean value of LH concentration of 1.68±0.05 ng/ml on day 1, while it peaked at 7.83±0.24 ng/ml on day 21. The sows in T3 (8 hours) had a mean value of LH concentration of 1.37±0.12 ng/ml on day 1, while it peaked at 8.01±0.26 ng/ml on day 21. The sows in T4 (12 hours) had a mean value of LH concentration of 1.29±0.07 ng/ml on day 1, while it peaked at 8.05±0.31 ng/ml on day 17.

4.2.13 Follicle Stimulating Hormone (FSH) Concentration in Sows from the Period of Intermittent Suckling to the Onset of Oestrus

Shown on Figure 4.10 was the result of the follicle stimulating hormone (FSH) concentration (ng/ml) in sows from the period of intermittent suckling to onset of oestrus. There was a gradual increase in the FSH concentration of the sows until there was a sharp increase which signified the peak of FSH concentration. The mean FSH concentration for sows in T1 (0 hours) was 1.37±0.14 ng/ml on day 1, while it peaked at 5.13±0.21 ng/ml on day 24. The sows in T2 (4 hours) had a mean FSH concentration of 1.85±0.04 ng/ml on day 1, while it peaked at 5.28±0.34 ng/ml on day 21. The sows in T3 (8 hours) had a mean FSH concentration of 1.39±0.18 ng/ml on day 1, while it peaked at 5.84±0.26 ng/ml on day 21. The sows in T4 (12 hours) had a mean FSH concentration of 1.63±0.09 ng/ml on day 1, while it peaked at 5.71±0.52 ng/ml on day 17.

4.2.14 Oestrogen Concentration in Sows from the Period of Intermittent Suckling to the Onset of Oestrus

Presented on figure 4.11 was the result of the oestrogen concentration (ng/ml) in sows from the period of intermittent suckling to onset of oestrus. The mean value for oestrogen concentration for sows in T1 (0 hours) was 25.36±2.78 pg/ml ng/ml on day 1 while it peaked at 136.75±4.38 pg/ml on day 21. The sows in T2 (4 hours) had a mean value of oestrogen concentration of 25.85±1.94 pg/ml on day 1 while it peaked at 127.64±4.26 pg/ml on day 17. The sows in T3 (8 hours) had a mean value of oestrogen concentration of 30.07±2.19 pg/ml on day 1 while it peaked at 133.74±3.58 pg/ml on day 17. The sows in T4 (12 hours) had a mean value of oestrogen concentration of 20.5±1.64 pg/ml on day 1 while it peaked at 81.51±3.17 pg/ml on day 17.

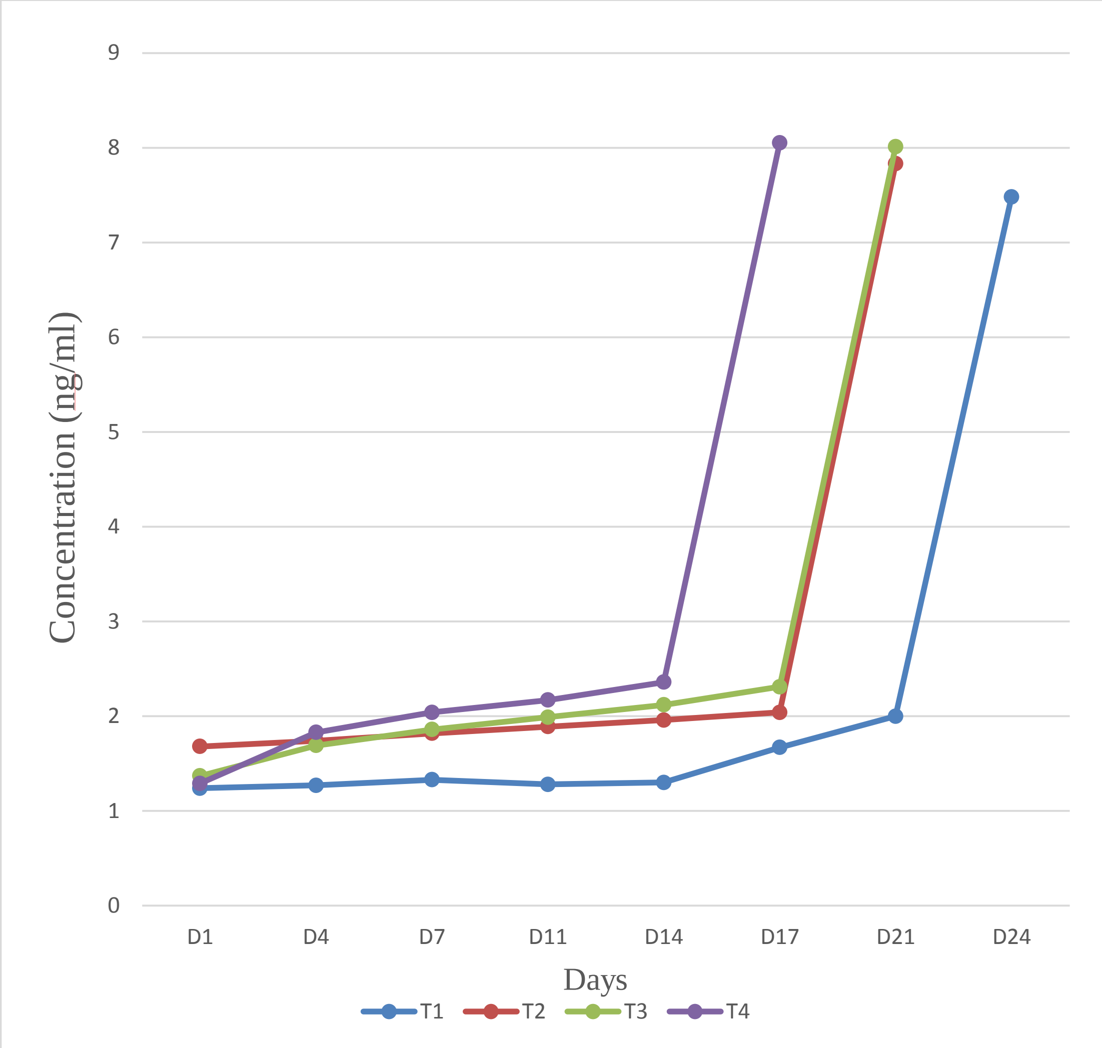

Figure 4.9: Luteinizing Hormone Concentration (ng/ml) in Sows from the Period of Intermittent Suckling to the Onset of Oestrus

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

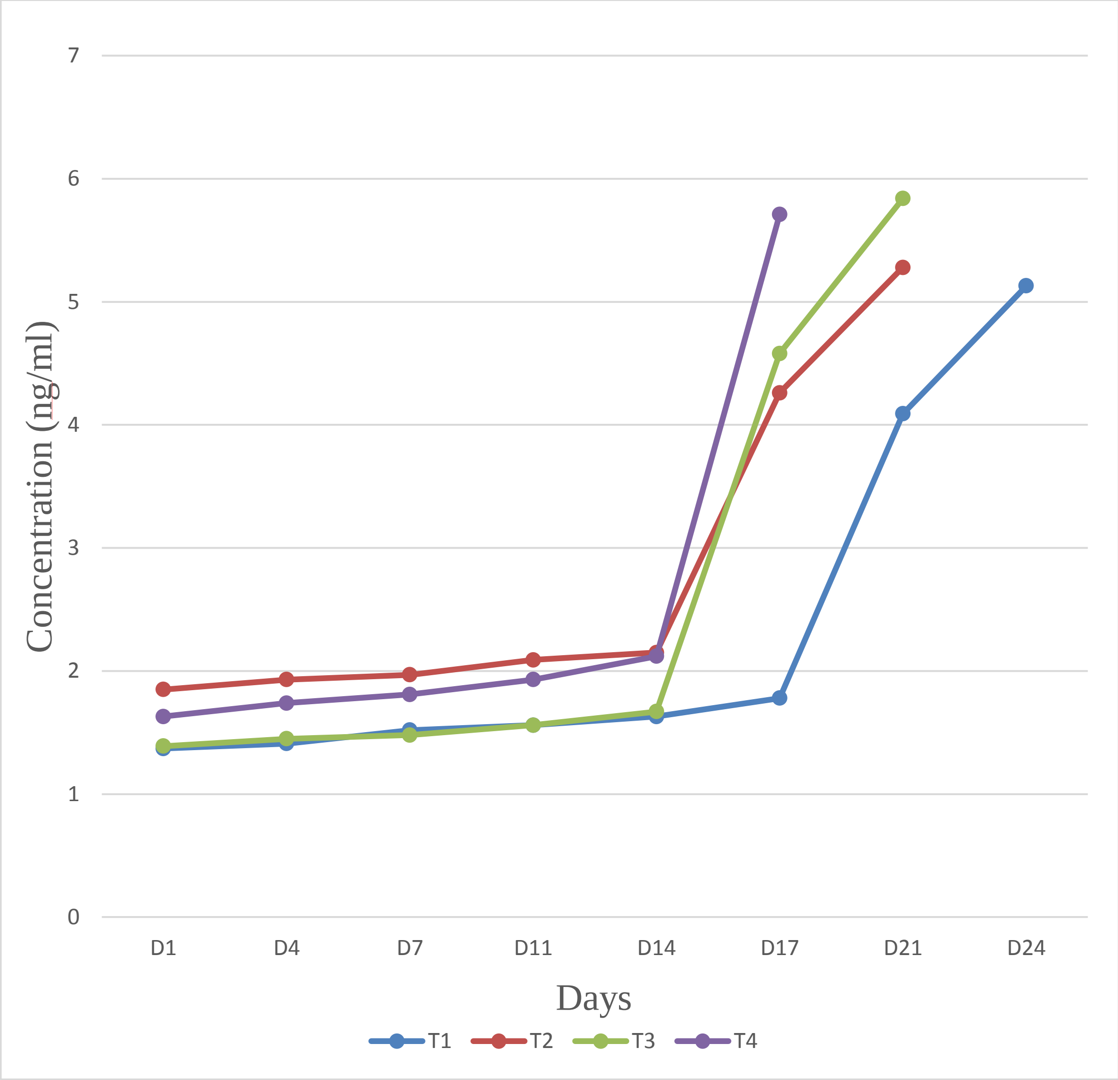

Figure 4.10: Follicle Stimulating Hormone Concentration (ng/ml) in Sows from the Period of Intermittent Suckling to the Onset of Oestrus

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

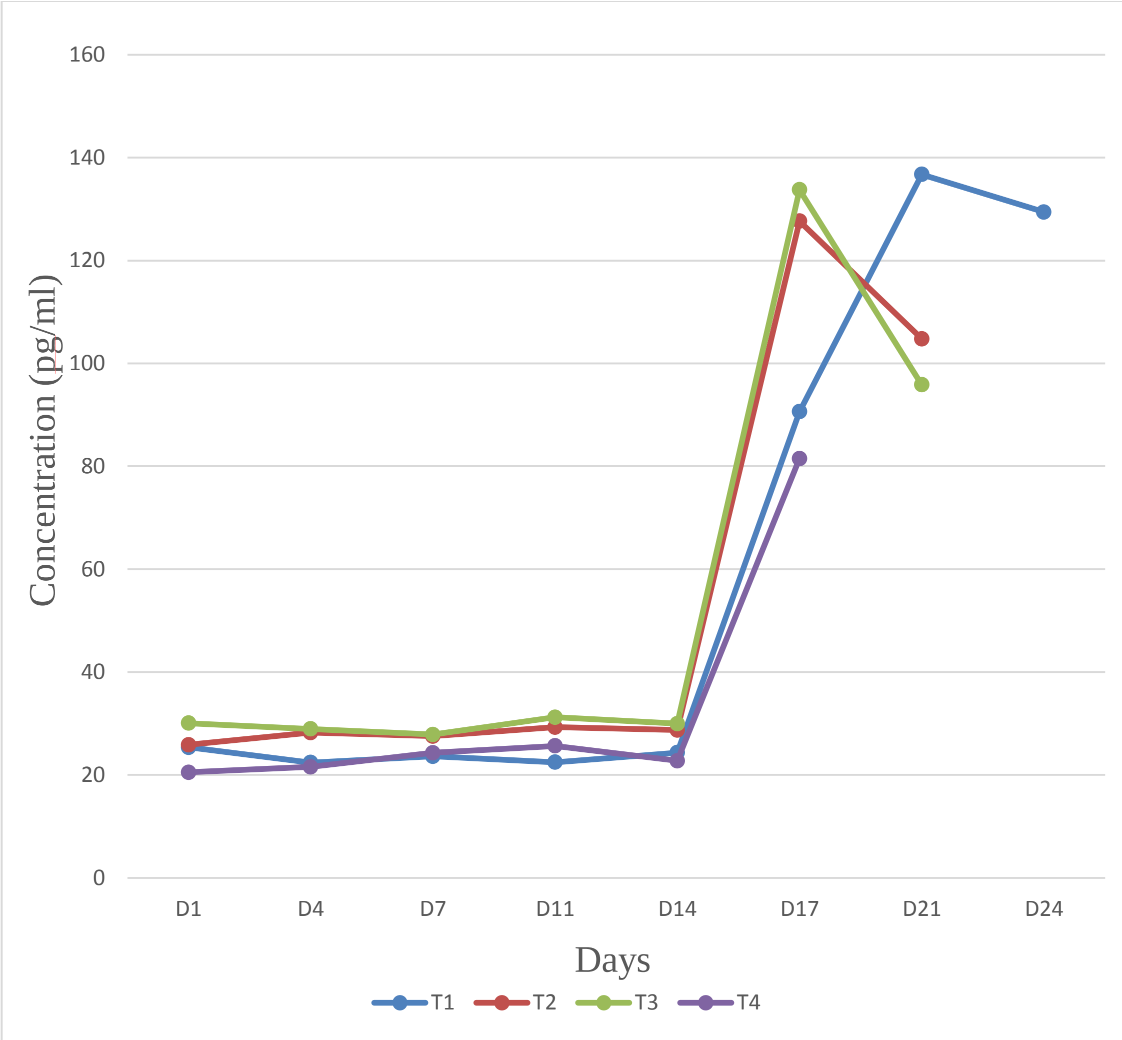

Figure 4.11: Oestrogen Concentration (pg/ml) in Sows from the Period of Intermittent Suckling to the Onset of Oestrus

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

4.3 Duration of Intermittent Suckling on Weanling Pigs Growth, Behaviour, Stress Response and Subsequent Reproductive Performance of the Dam

4.3.1 Growth Performance of Weanling Pigs after Intermittent Suckling

The growth performance of weanling pigs after intermittent suckling was as shown in Table 4.17. There were significant ($p<0.05$) differences among the treatments for all parameter measured. The mean values for the initial weight and feed conversion ratio showed that, T1 (0 hours) (6.22±0.26 kg; 2.99±0.26) was significantly ($p<0.05$) higher than T2 (4 hours) (5.59±0.38 kg; 2.87±0.22), T3 (8 hours) (5.51±0.21 kg; 2.83±0.16), and T4 (12 hours) (5.47±0.40 kg; 2.84±0.20) respectively. For average weight gain and average feed intake, T4 (12 hours) (5.56±0.50 kg; 15.77±0.62) and T3 (8 hours) (5.39±0.38 kg; 15.28±0.87) were significantly ($p<0.05$) higher than T2 (4 hours) (4.97±0.52 kg; 14.19±0.31) and T1 (0 hours) (4.21±0.43 kg; 12.62±0.23) respectively. Also, the mean values for the final weight showed that T4 (12 hours) (11.03±0.74 kg) and T3 (8 hours) (10.90±0.59 kg) were significantly ($p<0.05$) higher than T2 (4 hours) (10.56±0.78) and T1 (0 hours) (10.43±0.67 kg).

4.3.2 Corticosterone Concentration in Weanling Pigs after Intermittent Suckling

Shown on Figure 4.12 was the result of the corticosterone concentration (ng/ml) in weanling pigs after intermittent suckling. Animals in T1 (0 hours) were more stressed after weaning compared to those on T2 (4 hours), T3 (8 hours) and T4 (12 hours). The corticosterone concentration for T1 (0 hours) was the highest on day 4 (54.66 ng/ml) compared to T2 (4 hours), T3 (8 hours) and T4 (12 hours) which were 50.16 ng/ml, 47.02 ng/ml, and 45.08 ng/ml, respectively.

4.3.3 White Blood Cell Counts of Weanling Pigs after Intermittent Suckling

The result of white blood cell counts ($\times 10^3$ µl) of weanling pigs after intermittent suckling is shown in Table 4.18. There were significant ($p<0.05$) differences among the treatments from day 1 to 14. On days 1, 4, and 7, white blood cells in animals in T1 (0 hours) (9.48±0.35 $\times 10^3$ µl; 10.90±0.47 $\times 10^3$ µl; 9.57±0.32 $\times 10^3$ µl) was significantly ($p<0.05$) higher than T2 (4 hours) (9.18±0.42 $\times 10^3$ µl; 9.42±0.14 $\times 10^3$ µl;

9.08±0.91 $\times 10^3$ µl), T3 (8 hours) (8.20±0.58 $\times 10^3$ µl; 8.06±0.30 $\times 10^3$ µl; 8.71±0.70 $\times 10^3$ µl) and T4 (12 hours) (8.08±0.21 $\times 10^3$ µl; 8.35±0.81 $\times 10^3$ µl; 8.43±0.16 $\times 10^3$ µl), respectively. On days 11 and 14, white blood cells in animals in T1 (0 hours) (9.15±0.71 $\times 10^3$ µl; 8.73±0.32 $\times 10^3$ µl) was significantly (p<0.05) higher than T2 (4 hours) (8.55±0.89 $\times 10^3$ µl; 8.28±0.17 $\times 10^3$ µl), T3 (8 hours) (8.25±0.94 $\times 10^3$ µl; 8.34±0.63 $\times 10^3$ µl) and T4 (12 hours) (8.33±0.46 $\times 10^3$ µl; 8.46±0.21 $\times 10^3$ µl), respectively.

4.3.4 Lymphocyte Counts of Weanling Pigs after Intermittent Suckling

Shown on Table 4.19 was the result of lymphocyte counts (%) of weanling pigs after intermittent suckling. There was no significant (p>0.05) difference among the treatments for day 14. The mean values ranged from 46.67±0.36 % in T2 (4 hours) to 46.00±0.36 % in T1 (0 hours) and 46.00±0.24% in T4 (12 hours). However, there were significant (p<0.05) differences among the treatments from days 1 to 11. On day 1, lymphocytes in animals in T4 (12 hours) (43.67±0.31 %) and T3 (8 hours) (43.67±0.2 3 %) were significantly (p<0.05) higher than T2 (4 hours) and T1 (0 hours) (42.67±1.23 % and 40.00±0.65 %, respectively). On day 4, lymphocytes in animals in T3 (8 hours) (43.33±0.45 %) was significantly (p<0.05) higher than T2 (4 hours), T4 (12 hours) and T1 (0 hours) (42.67±0.81 %, 42.00±0.21 % and 41.67±0.57 %, respectively). On day 7, lymphocytes in animals in T3 (8 hours) (43.67±0.33 %) and T2 (4 hours) (43.33±0.68 %) were significantly (p<0.05) higher than T4 (12 hours) (43.00±0.69 %) and T1 (0 hours) (42.33±0.45 %). Also, on day 11, lymphocytes in animals in T4 (12 hours) (45.67±1.03 %) and T1 (0 hours) (45.00±0.37 %) were significantly (p<0.05) higher than T3 (8 hours) (44.33±0.59 %) and T2 (4 hours) (44.00±0.14 %).

4.3.5 Neutrophil Counts of Weanling Pigs after Intermittent Suckling

Presented on Table 4.20 was the result of neutrophil counts (%) of weanling pigs after intermittent suckling. There were significant (p<0.05) differences among the treatments from days 1 to 14. On days 1 and 4, neutrophils in animals in T1 (0 hours) (53.671.03 %; 52.00±0.21 %) was significantly (p<0.05) higher than T2 (4 hours) (51.33±0.92 %; 51.33±0.33 %), T3 (8 hours) (50.33±0.17 %; 50.00±0.74 %) and T4

(12 hours) (50.33±0.36 %, 51.33±0.18 %, respectively). On day 7, neutrophils in animals in T1 (0 hours) (51.33±0.37 %) and T4 (12 hours) (51.33±0.35 %) were significantly ($p<0.05$) higher than T2 (4 hours) (50.67±0.13 %) and T3 (8 hours) (50.67±1.24 %). On day 11, neutrophils in animals in T4 (12 hours) (49.33±0.32 %), T3 (8 hours) (49.00±0.85 %) and T2 (4 hours) (49.00±0.56 %) were significantly ($p<0.05$) higher than T1 (0 hours) (48.00±1.20 %). Also, on day 14, neutrophils in animals in T3 (8 hours) (48.00±0.27 %) was significantly ($p<0.05$) higher than T2 (4 hours) (46.00±0.68 %).

4.3.6 Monocyte Counts of Weanling Pigs after Intermittent Suckling

Presented on Table 4.21 was the result of monocyte counts (%) of weanling pigs after intermittent suckling. There were significant ($p<0.05$) differences among the treatments from days 1 to 14. On day 1, monocytes in animals in T1 (0 hours) (3.33±0.12 %) and T2 (4 hours) (3.33±0.04 %) were significantly ($p<0.05$) higher than T3 (8 hours) (2.33±0.10 %) and T4 (12 hours) (2.33±0.17 %). On day 4, monocytes in animals in T3 (8 hours) (3.67±0.13 %) was significantly ($p<0.05$) higher than T1 (0 hours) (3.00±0.06 %) but not different from T2 (4 hours) (3.33±0.21) and T4 (12 hours) (3.33±0.21). On day 7, monocytes in animals in T2 (4 hours) (3.33±0.16 %) was significantly ($p<0.05$) higher than T4 (12 hours) (2.67±0.20 %) but not different from T1 (0 hours) (3.00±0.04) and T3 (8 hours) (3.00±0.13). On day 11, monocytes in animals in T1 (0 hours) (3.67±0.18 %) was significantly ($p<0.05$) higher than T4 (12 hours) (3.00±0.24 %), T2 (4 hours) (2.67±0.06 %) and T3 (8 hours) (2.67±0.10 %). Also, on day 14, monocytes in animals in T2 (4 hours) (4.00±0.04 %) was significantly ($p<0.05$) higher than T4 (12 hours) (3.33±0.20 %), T3 (8 hours) (3.00±0.15 %) and T1 (0 hours) (2.67±0.22 %).

Table 4.17: Growth Performance of Weanling Pigs after Intermittent Suckling

Parameters	Hours of separation			
	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
Initial weight (Kg)	6.22±0.26[a]	5.59±0.38[b]	5.51±0.21[b]	5.47±0.40[b]
Final weight (Kg)	10.43±0.67[b]	10.56±0.78[b]	10.90±0.59[a]	11.03±0.74[a]
Average weight gain (Kg)	4.21±0.43[c]	4.97±0.52[b]	5.39±0.38[a]	5.56±0.50[a]
Average feed intake (Kg)	12.62±0.23[c]	14.19±0.31[b]	15.28±0.87[a]	15.77±0.62[a]
Feed conversion ratio	2.99±0.26[a]	2.87±0.22[b]	2.83±0.16[b]	2.84±0.20[b]

[a, b, c] Means in the same row with different superscripts are significantly different ($p<0.05$)

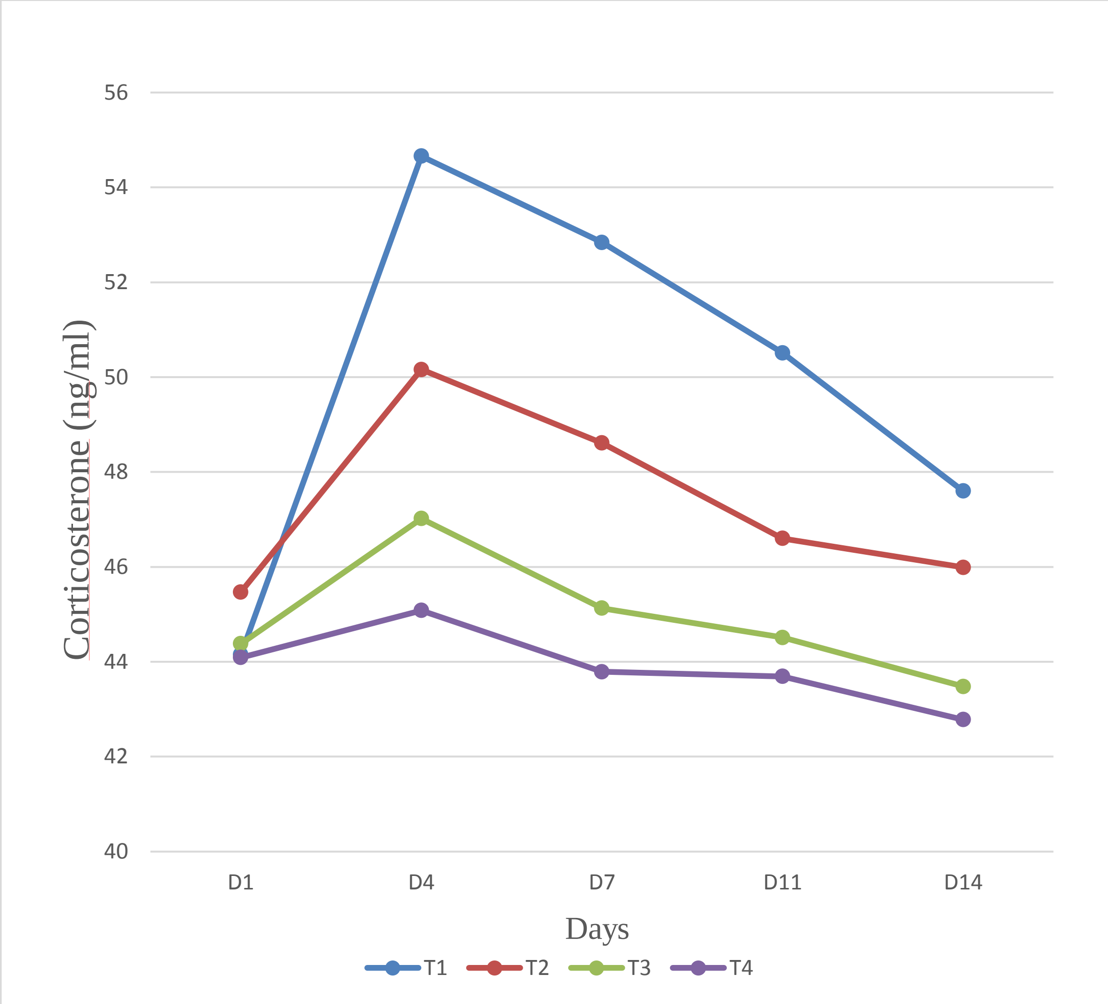

Figure 4.12: Corticosterone Concentration (ng/ml) in Weanling Pigs after Intermittent Suckling

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

Table 4.18: White Blood Cell Counts ($X10^3$ µl) of Weanling Pigs after Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	9.48 ± 0.35^a	9.18 ± 0.42^b	8.20 ± 0.58^c	8.08 ± 0.21^c
4	10.90 ± 0.47^a	9.42 ± 0.14^b	8.06 ± 0.30^c	8.35 ± 0.81^c
7	9.57 ± 0.32^a	9.08 ± 0.91^b	8.71 ± 0.70^c	8.43 ± 0.16^c
11	9.15 ± 0.71^a	8.55 ± 0.89^b	8.25 ± 0.94^b	8.33 ± 0.46^b
14	8.73 ± 0.32^a	8.28 ± 0.17^b	8.34 ± 0.63^b	8.46 ± 0.21^b

$^{a, b, c}$ Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4.19: Lymphocyte Counts (%) of Weanling Pigs after Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	40.00 ± 0.65^{c}	42.67 ± 1.23^{b}	43.67 ± 0.23^{a}	43.67 ± 0.31^{a}
4	41.67 ± 0.57^{c}	42.67 ± 0.81^{b}	43.33 ± 0.45^{a}	42.00 ± 0.21^{c}
7	42.33 ± 0.45^{c}	43.33 ± 0.68^{a}	43.67 ± 0.33^{a}	43.00 ± 0.69^{b}
11	45.00 ± 0.37^{a}	44.00 ± 0.14^{b}	44.33 ± 0.59^{b}	45.67 ± 1.03^{a}
14	46.00±0.36	46.67±0.28	46.33±0.53	46.00±0.24

$^{a, b, c}$ Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4.20: Neutrophil Counts (%) of Weanling Pigs after Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	53.67 ± 1.03^{a}	51.33 ± 0.92^{b}	50.33 ± 0.17^{c}	50.33 ± 0.36^{c}
4	52.00 ± 0.21^{a}	51.33 ± 0.33^{b}	50.00 ± 0.74^{c}	51.33 ± 0.18^{b}
7	51.33 ± 0.37^{a}	50.67 ± 0.13^{b}	50.67 ± 1.24^{b}	51.33 ± 0.35^{a}
11	48.00 ± 1.20^{b}	49.00 ± 0.56^{a}	49.00 ± 0.85^{a}	49.33 ± 0.32^{a}
14	47.33 ± 1.04^{ab}	46.00 ± 0.68^{b}	48.00 ± 0.27^{a}	47.33 ± 0.61^{ab}

$^{a, b, c}$ Means in the same row with different superscripts are significantly different ($p<0.05$)

Table 4.21: Monocyte Counts (%) of Weanling Pigs after Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	3.33±0.12[a]	3.33±0.04[a]	2.33±0.10[b]	2.33±0.17[b]
4	3.00±0.06[b]	3.33±0.21[ab]	3.67±0.13[a]	3.33±0.21[ab]
7	3.00±0.04[ab]	3.33±0.16[a]	3.00±0.13[ab]	2.67±0.20[b]
11	3.67±0.18[a]	2.67±0.06[b]	2.67±0.10[b]	3.00±0.24[b]
14	2.67±0.22[c]	4.00±0.04[a]	3.00±0.15[bc]	3.33±0.20[b]

[a, b, c] Means in the same row with different superscripts are significantly different ($p<0.05$)

4.3.7 Eosinophil Counts of Weanling Pigs after Intermittent Suckling

Presented on Table 4.22 was the result of eosinophil counts (%) of weanling pigs after intermittent suckling. There were significant ($p<0.05$) differences among the treatments from days 1 to 14. On day 1, eosinophils in animals in T4 (12 hours) (3.67±0.09 %) and T3 (8 hours) (3.67±0.21 %) were significantly ($p<0.05$) higher than T1 (0 hours) (3.00±0.10 %) but not different from T2 (4 hours) (3.33±0.14). On day 4, eosinophils in animals in T1 (0 hours) (3.33±0.23 %) and T4 (12 hours) (3.33±0.19 %) were significantly ($p<0.05$) higher than T2 (4 hours) (2.67±0.15 %)) and T3 (8 hours) (2.67±0.05 %). On day 7, eosinophils in animals in T1 (0 hours) (3.33±0.07 %) was significantly ($p<0.05$) higher than T2 (4 hours) (2.67±0.18 %) and T3 (8 hours) (2.67±0.21 %). On day 11, T2 (4 hours) (4.33±0.03 %) and T3 (8 hours) (4.00±0.18 %) were significantly ($p<0.05$) higher than T1 (0 hours) (3.33±0.19 %) and T4 (12 hours) (2.00±0.24 %). Also, on day 14, eosinophils in animals in T1 (0 hours) (4.00±0.19 %) and T2 (4 hours) (3.33±0.03 %) were significantly ($p<0.05$) higher than T3 (8 hours) (2.67±0.17 %) and T4 (12 hours) (3.00±0.21 %)

4.3.8 Feeding Behaviour of Weanling Pigs after Intermittent Suckling

Presented on Figure 4.13 was the feeding behaviour of weanling pigs after intermittent suckling. The weanling pigs earlier on continuous suckling spent lesser time feeding than those separated from the sow for 4, 8, and 12 hours. The T1 (0 hours) had the lowest value on day 1 (8.20 %), while the highest value was on day 9 (48.45 %). The T2 (4 hours) had the lowest value on day 1 (37.45 %), while the highest value was on day 7 (51.45 %). The T3 (8 hours) had the lowest value on day 1 (43.8 %), while the highest value was on day 9 (51.5 %). The T4 (12 hours) had the lowest value on day 1 (45.25 %), while the highest value was on day 10 (51.5 %).

4.3.9 Aggressive Behaviour of Weanling Pigs after Intermittent Suckling

Presented on Figure 4.14 was the aggressive behaviour of weanling pigs after intermittent suckling. The weanling pigs earlier on continuous suckling were more aggressive than those separated from the sow for 4, 8, and 12 hours. The T1 (0 hours) had the highest value on day 1 (11.75 %), while the lowest value was on day 10 (1.00 %). The T2 (4 hours) had the highest value on day 7 (1.00 %), while the lowest values were on day 2, 3, 5, 6 and 10 (0.00 %). The T3 (8 hours) had the highest value on day 10 (0.70 %), while the lowest values were on day 1, 2, 5, 6 and 7 (0.00 %). The T4 (12 hours) had the highest value on day 2 (0.55 %), while the lowest values were on day 1, 3, 4, 6, 7, 8 and 9 (0.00 %).

4.3.10 Manipulative Behaviour of Weanling Pigs after Intermittent Suckling

Shown on Figure 4.15 was the manipulative behaviour of weanling pigs after intermittent suckling. The T1 (0 hours) had the highest value on day 2 (11.35 %), while the lowest value was on day 8 (6.25 %). The T2 (4 hours) had the highest value on day 6 (9.2%), while the lowest value was on day 9 (4.2 %). The T3 (8 hours) had the highest value on day 3 (5.9 %), while the lowest value was on day 5 (1.75 %). The T4 (12 hours) had the highest value on day 1 (5.70 %), while the lowest value was on day 7 and 9 (1.75 %).

4.3.11 Reproductive Performance of Weaned Sows after Intermittent Suckling

The reproductive performance of weaned sows after intermittent suckling is as shown in Table 4.23. There was no significant ($p>0.05$) difference among the treatments for the percentage conception which was 100.00 % for all the treatments, average litter size and number of piglets born alive which ranged from 8.00±1.00 in T4 (12 hours) to 7.00±1.22 in T1 (0 hours), number of still births which was 0.00 for all the treatments, and average litter birth weight which ranged from 1.44±0.12 kg in T3 (8 hours) to 1.37±0.23 kg in T2 (4 hours). However, there was significant ($p<0.05$) difference among the treatments for weaning to oestrus interval. The mean values for weaning to oestrus interval showed that, T1 (0 hours) (7.00±1.00) and T2 (4 hours) (6.00±0.71) were significantly ($p<0.05$) higher than T3 (8 hours) (4.00±0.71) and T4 (12 hours) (4.00±0.00).

Table 4.22: Eosinophil Counts (%) of Weanling Pigs after Intermittent Suckling

	Hours of separation			
Day	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
1	3.00 ± 0.10^{b}	3.33 ± 0.14^{ab}	3.67 ± 0.21^{a}	3.67 ± 0.09^{a}
4	3.33 ± 0.23^{a}	2.67 ± 0.15^{b}	2.67 ± 0.05^{b}	3.33 ± 0.19^{a}
7	3.33 ± 0.07^{a}	2.67 ± 0.18^{b}	2.67 ± 0.21^{b}	3.00 ± 0.02^{ab}
11	3.33 ± 0.19^{b}	4.33 ± 0.09^{a}	4.00 ± 0.18^{a}	2.00 ± 0.24^{c}
14	4.00 ± 0.19^{a}	3.33 ± 0.03^{a}	2.67 ± 0.17^{b}	3.00 ± 0.21^{b}

$^{a, b, c}$ Means in the same row with different superscripts are significantly different ($p<0.05$)

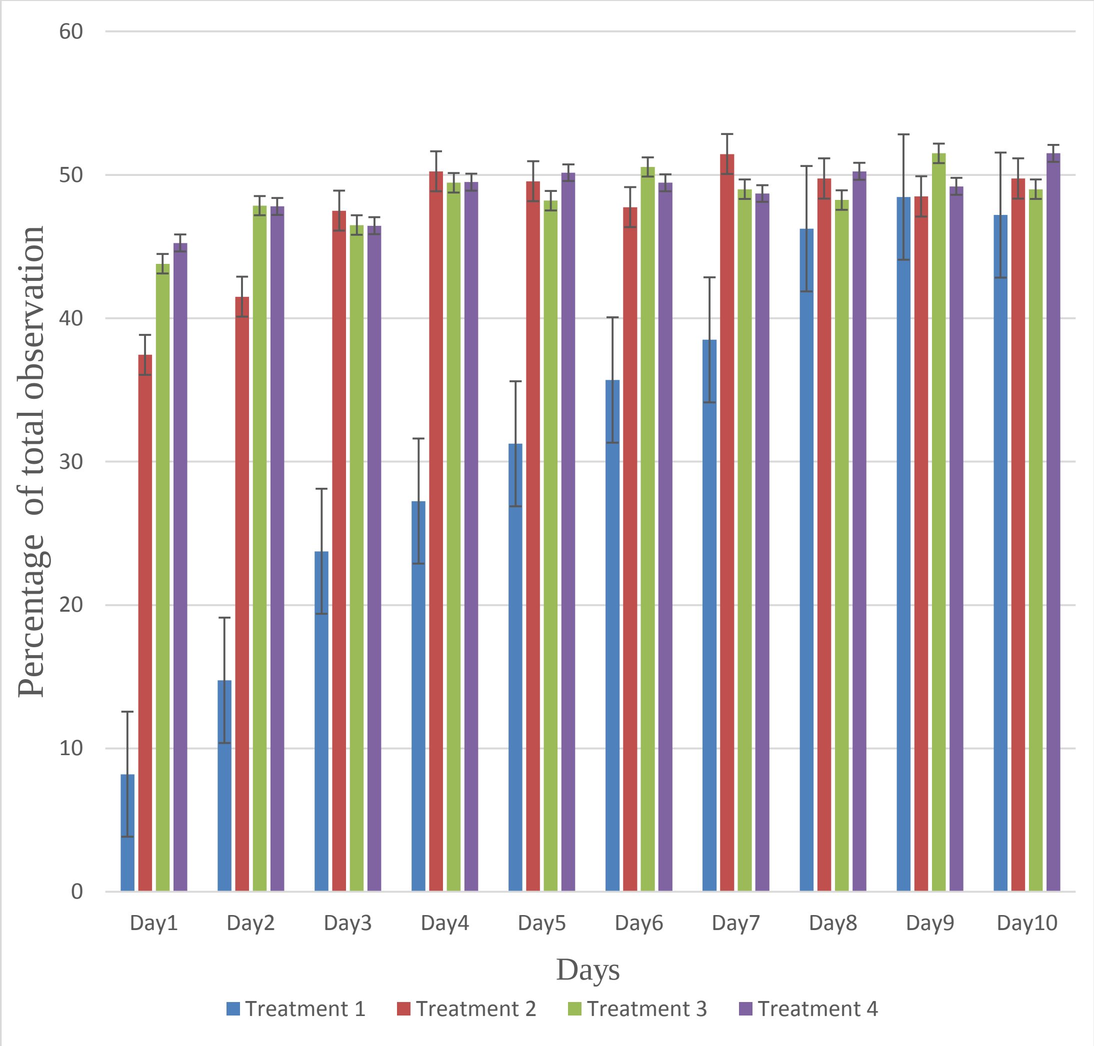

Figure 4.13: Feeding Behaviour of Weanling Pigs after Intermittent Suckling

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

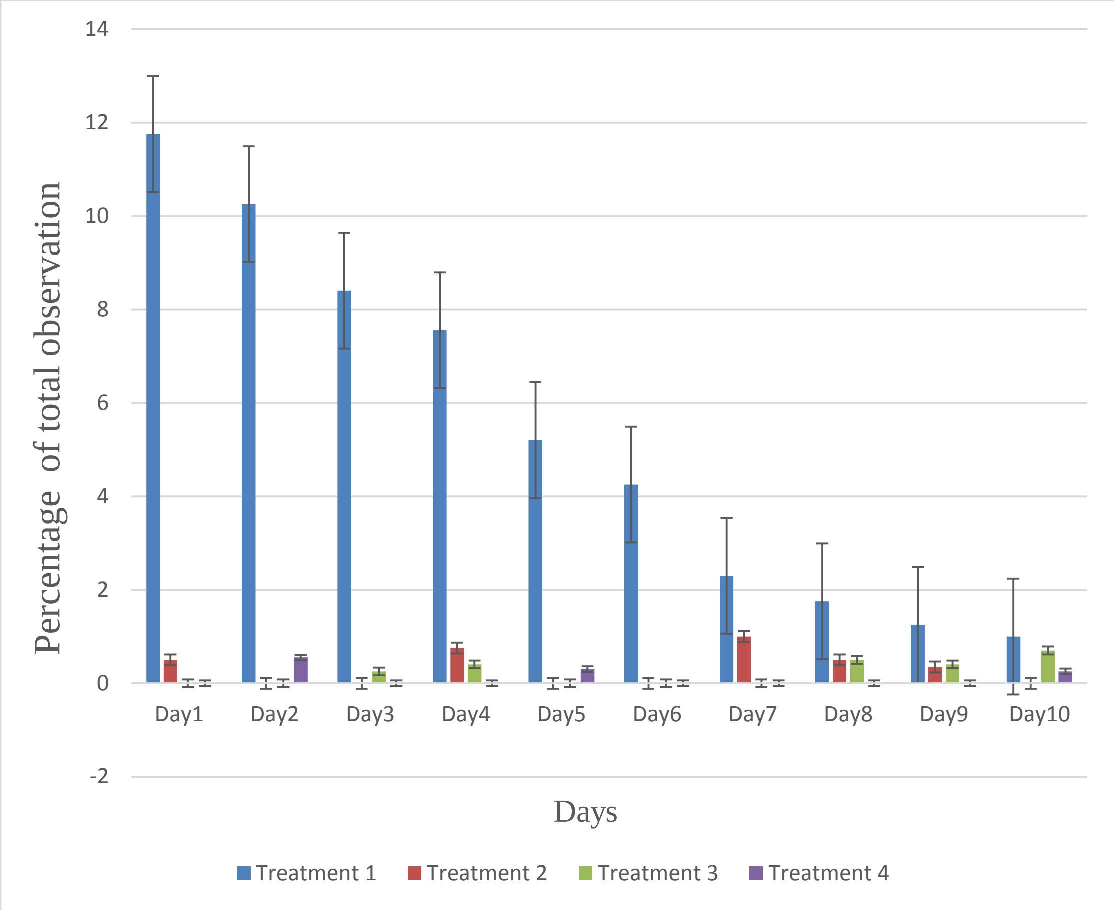

Figure 4.14: Aggressive Behaviour of Weanling Pigs after Intermittent Suckling

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

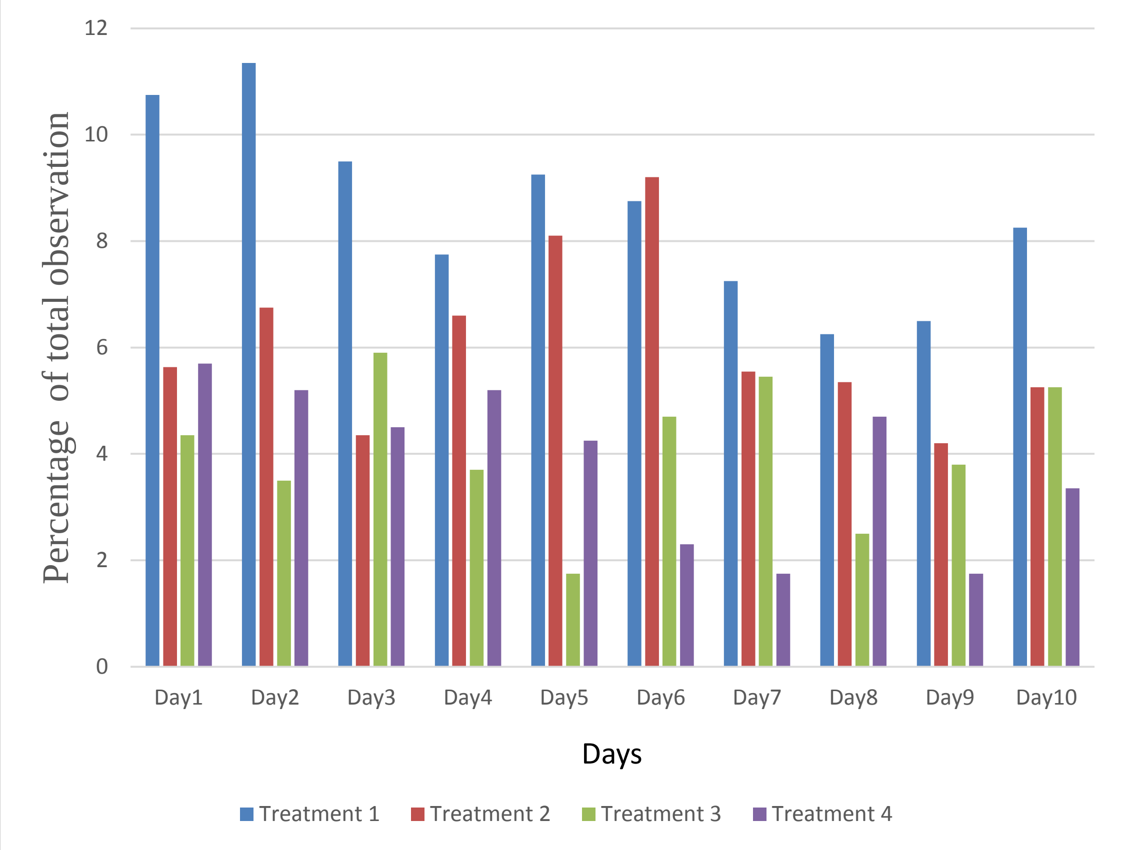

Figure 4.15: Manipulative Behaviour of Weanling Pigs after Intermittent Suckling

Treatment 1: Continuous suckling (0 hours)

Treatment 2: 4 hours of separation

Treatment 3: 8 hours of separation

Treatment 4: 12 hours of separation

Table 4.23: Reproductive Performance of Weaned Sows after Intermittent Suckling

Parameters	Hours of separation			
	T1 (0 hours)	T2 (4 hours)	T3 (8 hours)	T4 (12 hours)
Weaning to oestrus interval (days)	7.00±1.00[a]	6.00±0.71[a]	4.00±0.71[b]	4.00±0.00[b]
Percentage conception (%)	100.00	100.00	100.00	100.00
Average litter size	7.00±1.22	7.00±0.71	7.00±0.71	8.00±1.00
Number of piglets born alive	7.00±1.22	7.00±0.71	7.00±0.71	8.00±1.00
Number of still births	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Average litter birth weight (Kg)	1.40±0.16	1.37±0.23	1.44±0.12	1.41±0.28

[a, b] Means in the same row with different superscripts are significantly different ($p<0.05$)

CHAPTER FIVE

DISCUSSION

5.1 Dam Reproductive Performance, Growth, Behavioural And Stress Responses of Weanling Pigs to Weaning Time

5.1.1 Growth Performance of Weanling Pigs Weaned at Different Weaning Time

The growth performance of weanling pigs weaned at different weaning time revealed that weaning time had effect on the pigs' performance. The findings of this study indicated that average feed intake, average weight gain, and final weight of weanling pigs weaned at 6 weeks and 8 weeks were significantly higher than those weaned at 4 weeks. Kuller *et al*. (2004) stated that the growth rate of weanling pigs is dependent on their feed consumption, and those pigs that consume feed at a faster rate will grow faster than those that consume less feed. The feed conversion ratio for weanling pigs weaned at 4 weeks that was significantly higher than those weaned at 6 weeks and 8 weeks could be as result of a more developed gut in weanling pigs weaned at 6 weeks and 8 weeks to handle solid feed.

Weaning ends access to suckling milk from the sow. However, intake of a solid diet by the weanling pigs can be delayed for few days based on the extent of the severity of weaning stress on the animals (Pluske *et al*., 1997). The delay in the intake of solid feed leads to a reduction in nutrient supply to the small intestine, causing the small intestinal villi to shorten, and reducing the capacity for absorption. (Pluske *et al*., 1997). Brooks and Tsourgiannis (2003) reported that weaning piglets earlier than 5 weeks resulted into reduced feed intake and weight gain immediately post-weaning. Moreover, some studies (van Beers-Schreurs *et al*., 1998; Berkeveld *et al*., 2009) have shown a positive relationship between villus height and feed intake, highlighting the significance of adequate feed intake for optimal function of the intestine. In European conventional pig farming, the weaning of piglets typically occurs approximately at age of 3 to 4 weeks (Diana *et al*., 2016). Consequently, weaning is linked to a decline in nutrient intake and growth, which adversely affects the structure as well as the function of the intestines (Berkeveld *et al*., 2009).

5.1.2 Corticosterone Concentration in Weanling Pigs Weaned at Different Weaning Time

Serum corticosterone was used as a physiological indicator of stress in this study. Moberg and Mench (2000) described stress as a biological reaction that occurs when an organism perceives a disruption to its internal balance. It arises when an animal is unable to effectively cope with a physiological or behavioural challenge. When examining the potential impacts of weaning time on the welfare of weanling pigs, it is crucial to recognize instances where animals are incapable of physiologically or behaviourally managing the challenge (Moberg and Mench, 2000). In other words, it is important to identify when there is a biological toll on the animals (Hemsworth *et al*., 2014).

Elevation of serum corticosterone concentration in stressful situation is an adaptation response of the organism to a changing environment (Jarvis *et al*., 2006). In this study, the corticosterone concentration of weanling pigs weaned at 4 weeks, 6 weeks, and 8 weeks were measured. Weanling pigs undergo weaning stress irrespective of the age at which they are weaned however, the severity of the weaning stress on the animals depends on the age at which they are weaned (Dybkjaer, 1992). The weanling pigs weaned at 4 weeks were more stressed after weaning compared to those weaned at 6 weeks and 8 weeks. Probably, weaning early induces more pronounced stress response. The rise in corticosterone concentration may be attributed to the psychological stress of weaning which was caused by maternal separation and abrupt change in nutrient source i.e from milk to solid feed. Mason *et al*. (2003) reported that corticosterone, a physiological reaction to stress is higher in weanling pigs which ingest little or no creep feed before weaning. Also, Campbell *et al*. (2013) reported that the removal of sow milk and environment changes led to a drastic reduction in feed intake which was caused by loss of appetite (anorexia). Research by Klemcke and Pond (1991) revealed that separating piglets from their mother overnight during the weaning process is linked to increased levels of basal corticosterone concentration in newly weaned pigs. Corticosterone concentration in the blood has been used to access stress in agricultural animals (McGlone *et al*., 1993; Stull and McDonough, 1994). Furthermore, the weaning of piglets at the age of 3 to 4 weeks has been demonstrated to trigger stress signaling pathways that play a role in mediating and contributing to intestinal dysfunction, such as heightened permeability in small intestine, which is related with the weaning process (Moeser *et al*., 2007).

5.1.3 White Blood Cell and its Differentials in Weanling Pigs Weaned at Different Weaning Time

White blood cell was also used as physiological indicator of stress in this study. Haematological parameters such as white blood cell are good indicators of physiological and pathological changes in animals (Adenkola and Durotoye, 2004). In this study, the higher white blood cell counts observed in weanling pigs weaned at 4 weeks when compared to those weaned at 6 weeks and 8 weeks, can be attributed to the weaning stress (Buckham-Sporer *et al*., 2008). This is suggested to be as a result of the mobilisation of white blood cells from their reserves to the peripheral circulation, likely due to their inhibitory effect on circulating corticosterone levels, which are known to rise in animals experiencing stress (Adenkola *et al*., 2009). This is because, the elevation of corticosterone release during stress in animals can amplify vulnerability to diseases and undermine the functioning of the immune system. However, the mean white blood cell count values obtained from this study were similar to the reference value (7-20 $\times 10^3/mm^3$) as documented by Research Animal Resources, (2009).

One of the useful stress indicator is the changes in white blood cell differential counts particularly the neutrophil:lymphocyte ratio (N:L). In this experiment, on day 4, the lymphocyte count reduced for all the treatments but the apparent reduction was more in weanling pigs weaned at 4 weeks. However, the neutrophil count increased. As glucocorticoid concentration increases, lymphocyte numbers decrease whereas number of neutrophils tends to increase. Neutrophils are the first line of defense in an organism's immune system. When there is a threat to the immune system of an organism, the neutrophils are produced more due to their anti-inflammatory activities and the destruction of infiltrating micro-organisms. The result of this study is in agreement with Zahorec (2001) who reported that as glucocorticoids concentration increased, neutrophil counts increased, while lymphocyte count decreased.

5.1.4 Feeding Behaviour of Weanling Pigs Weaned at Different Weaning Time

The result of this study showed that weanling pigs weaned at 4 weeks of age spent lesser time feeding than those weaned at 6 and 8 weeks and this caused a reduction in their weight gain compared to other treatments. This may be due to maternal separation and changes in nutrition source from milk to solid feed. However, the time spent feeding gradually increased as days passed. The intake of solid feed naturally rises as the piglets grow older, but in commercial rearing systems, piglets are weaned before they attain nutritional independence from the sow.

The significant distress exhibited by piglets during early weaning can be attributed not only to their reliance on the sow's milk but also to their social dependency on her. Numerous experiments have examined the behavioural as well as performance implications of early weaning in pigs, yet only a limited number have specifically investigated feed consumption, typically by assessing feeding behaviour or intake immediately following weaning. For instance, Dritz *et al*. (1996) found that piglets weaned at 19 days of age exhibited higher average daily feed intake compared to those weaned at 9 days of age. Also, Gonyou *et al*. (1998) observed that weanling pigs spent only half the time eating during the initial 48 hours after weaning at 12 days of age compared to those that were weaned at 21 days of age. In another study by Worobec *et al*. (1999), it was reported that weanling pigs weaned at 28 days of age consumed twice as much feed on average compared to those weaned at 14 days of age. Main *et al*. (2004) support the weaning of weanling pigs between 12 and 21 days of age, noting significant enhancements in feed intake and weight gains when weaning occurred at older ages. Colson *et al*. (2006) noticed a notable reduction in the duration of the growth check phase when weanling pigs were weaned at 28 days rather than 21 days of age, potentially attributed to higher feed intake.

While it is recognized that solid feed consumption increases with age (Fraser *et al*., 1998), the observed higher feed intakes in older weaned piglets may also be influenced by other factors, such as heightened distress experienced by younger piglets during weaning.

5.1.5 Aggressive Behaviour of Weanling Pigs Weaned at Different Weaning Time

Aggression commonly occurs at weaning especially among piglets weaned at younger age. This study showed that piglets weaned at 4 weeks of age were more aggressive than those weaned at 6 and 8 weeks and this may be due to depression caused by maternal separation. However, the aggresiveness gradually reduced as days passed. Separating piglets from their dams results in the manifestation of aggressive behaviour, which is a prominent consequence. Widowski *et al*. (2008) noted that early abrupt weaning often leads to increased instances of agonistic interactions, distress vocalizations as well as abnormal and stereotypic behaviours among piglets. Jarvis *et al*. (2008) attributed this aggression to the necessity of re-establishing the social hierarchy within the litter after the dam's absence. Additionally, stress can alter the cues emitted by piglets, affecting recognition by their littermates. For instance, studies have shown that vocalizations of stressed piglets may differ in quality from those of non-stressed individuals, as observed in cases of pain or distress (Taylor and Weary, 2000; Dupjan *et al*., 2008). Similarly, fear can modify olfactory cues released in urine, as demonstrated in previous research (McGlone, 1985; Vieuille-Thomas and Signoret, 1992; Amory and Pearce, 2000). Moreover, stressed piglets may exhibit alterations in behavioural postures that serve as visual cues for recognising their peers (McLeman *et al*., 2005). It has been suggested that piglets vocalise during weaning as a means to communicate their need for social reunion or maternal attention (Newberry and Swanson, 2008).

5.1.6 Manipulative Behaviour of Weanling Pigs Weaned at Different Weaning Time

Behaviours such as belly nosing as well as manipulating pen or littermates can indicate distress in piglets (Dybkjaer, 1992). In this study, piglets weaned at age of 4 weeks exhibited the highest level of manipulative behaviour when compared to the other treatments, suggesting that as the age at which piglets are weaned increases, the expression of manipulative behaviour by the weanling pigs decreases. Belly nosing and tail biting are some of the manipulative behaviour frequently seen in weanling pigs, particularly those weaned at an early age (Worobec *et al.*, 1999). The exact causes of belly nosing have not been definitively determined, but it has been proposed that this behaviour represents the persistence or redirection of sucking behaviour in piglets after being separated from the sow (Dybkjaer, 1992). Belly nosing is not observed in naturally weaned piglets (Jensen, 1995), and weaning piglets at a later age has been shown to significantly decrease the occurrence of this behaviour (Worobec *et al*., 1999). The inclination to engage in belly nosing may also be linked to the piglet's response to unfamiliar feed after weaning. It has been suggested that if piglets fail to adapt to or compete for the provided feed, they may resort to alternative behaviours, such as manipulating other piglets.

5.1.7 Growth Performance of Lactating Sows with Piglets Weaned at Different Weaning Time

In this study, the weight loss in sows separated for 8 hours was significantly higher than that of those separated for 4 hours and 0 hours. This could be as a result of longer lactation length of sows separated for 8 hours. Sows face drastic metabolic changes during lactation possibly because they are often catabolic and lose weight during lactation. This could be as a result of the fact that their feed intake is not always sufficient to meet up with the nutrient requirement for milk production. Therefore, the sow mobilizes the tissue reserves in order to meet up thereby losing weight. Therefore, the longer the lactation length, the more the sow loses weight. Intermittent suckling has been reported to reduce weight loss in sows during lactation as well as weaning to oestrus interval (Kuller *et al*., 2004).

5.1.8 Reproductive Performance of Sows Weaned at Different Weaning Time

The sow's metabolic state has an impact on the reproductive performance. The body condition of the sow determines how soon it will return back to oestrus after weaning. Due to the lactation process, the sow commonly experiences a catabolic state, leading to potential reproductive challenges following weaning (Foxcroft *et al*., 1996). For sows that losses weight excessively during lactation, they need more time to attain optimal body condition for reproduction and this increases the weaning to oestrus interval. This was evident from the result of this study as it took sows separated for 8 hours an average of 10 days to return to oestrus after weaning. Also, the percentage conception and litter size was lower compared to those separated for 0 hours and 4 hours**.** This aligns with the findings of Foxcroft *et al*. (1996), who observed that a catabolic state has a detrimental impact on the weaning-to-oestrus interval. Similarly, Vesseur *et al*. (1994) demonstrated that the weaning-to-oestrus interval was extended when weight loss surpassed 12.5%, particularly in first-parity sows. However, Kuller *et al*. (2004) reported no association between sow weight loss and weaning-to-oestrus interval. The sows included in their study experienced a weight loss of less than 8%, which may not have been sufficient to result in a prolonged weaning-to-oestrus interval.

5.2 Duration of Intermittent Suckling on Piglets' Growth, Behaviour, Stress Response and Subsequent Reproductive Performance of the Dam

5.2.1 Growth Performance of Piglets Before and During Intermittent Suckling

In this study, intermittent suckling increased intake of creep feed during lactation. However, there was reduction in weight gain with increasing hours of separation. The reduction in weight gain was apparently due of decrease in milk intake by the piglets, and the piglets were unable to make-up for their milk intake deficit during the increasing hours of separation from the sow. This aligns with results of Kuller *et al*. (2004) and Diana *et al*. (2016) who reported that piglets subjected to Intermittent suckling had higher creep feed intake but a lower weight gain due to reduction in milk intake compared to those on continuous suckling. In another study by Plagge and Van der Peet-Schwering (1998), the impact of intermittent suckling was not observed, possibly because of the cohabitation of control and intermittent suckling piglets in the same room. Nursing activities generate noise and are synchronised within a single room. Intermittent suckling piglets, which lack access to the sow, can hear these nursing sounds but are unable to initiate feeding. This likely resulted in heightened restlessness and did not motivate the piglets to approach the feeder for feeding. In this experiment, the potential restlessness was potentially mitigated by separating the intermittent suckling and control sows into separate rooms.

5.2.2 Corticosterone Concentration in Piglets during Intermittent Suckling

Serum corticosterone was used as a physiological indicator of stress in this study. According to Moberg and Mench (2000), stress is a physiological reaction triggered when an organism recognises a disturbance to its internal balance. Stress occurs when an animal is not able to physiologically or behaviourally cope with a challenge. Rising levels of corticosterone in the bloodstream during stressful situations represent an adaptive response of the organism to environmental changes, as explained by Jarvis *et al*. (2006). Nevertheless, the release of excessive corticosterone under stress in animals can heighten their vulnerability to diseases and weaken the immune system. In this study, the piglets separated from the dam for 4, 8, and 12 hours were stressed and the severity of stress increased with the corresponding increase in hours of separation for the first few days of separation, while piglets that were not separated were relatively stable. This increased corticosterone concentration may be attributed to stress due to maternal separation. This agrees with results of Diana *et al*. (2016) who reported that piglets subjected to intermittent suckling had higher level of corticosterone concentration in their blood compared to those on continuous suckling**.** The release of corticosterone during periods of stress in animals has the potential to amplify their susceptibility to diseases and compromise the functionality of the immune system.

5.2.3 White Blood Cell Count and its Differentials in Piglets during Intermittent Suckling

White blood cell count was also used as physiological indicator of stress in this study. Haematological parameters such as white blood cell count are good indicators of physiological and pathological changes in animals (Adenkola and Durotoye, 2004). In this study, there was significant increase in the white blood cell count with increasing hours of separation on the 4th day**.** This could be ascribed to the stress resulting from the separation from the sow, which triggers the mobilisation of leukocytes from their reservoir to the peripheral circulation, likely due to their inhibitory effect on circulating corticosterone, known to rise in animals experiencing stress. Nevertheless, the mean values of white blood cell count obtained from this investigation were witihn the reference value documented by Mitruka and Rawnsley (1977).

One of the useful stress indicator is the changes white blood cell differential counts particularly the neutrophil:lymphocyte ratio (N:L). In this experiment, on day 4, the neutrophil counts increased for all the treatments except for piglets that were not separated. However, the reverse was the case for lymphocyte count as they reduced. As glucocorticoid concentration increases, lymphocyte numbers tend to decrease whereas number of neutrophils tends to increase. Neutrophils are the first line of defense in an organism's immune system. When there is a threat to the immune system of an organism, the neutrophils are more produced due to their anti-inflammatory activities and the destruction of infiltrating micro-organisms. The result of this study is in agreement with Zahorec (2001) who reported that as glucocorticoids concentration increased, neutrophil counts increased while lymphocyte count decreased.

5.2.4 Feeding and Aggressive Behaviour of Piglets during Intermittent Suckling

The result of this study showed that piglets on continuous suckling spent more time feeding on creep feed than those that were separated from the dam for 4, 8 and 12 hours for the first few days of intermittent suckling despite having creep feed as the only source of nutrient during the period of separation. This may be due to depression which resulted from maternal separation and changes in nutrition source during the period of separation. However, the time spent feeding for the piglets on varying hours of separation gradually increased as days pass. This agrees with the findings of Berkeveld *et al*. (2007) who reported gradual increase in feeding behaviour with increasing hours of separation (0h, 6h, 12h). Piglets on varying hours of separation were more aggressive than those on continuous suckling and this may be due to depression caused by maternal separation. However, the aggresiveness gradually reduced as days pass. This agrees with the findings of Berkeveld *et al*. (2007) who reported increased aggressive behaviour with increasing hours of separation (0 h, 6 h, 12 h).

5.2.5 Manipulative Behaviour of Piglets during Intermittent Suckling

Manipulative behaviours such as belly nosing as well as manipulating pen or littermates can be signs of piglet distress (Dybkjaer, 1992). In this study, there was no particular trend in the expression of manipulative behaviour by the piglets making it difficult to draw firm conclusions. Belly nosing and tail biting are some of the manipulative behaviour often seen in piglets subjected to maternal separation especially at the early stage of intermittent suckling. The exact reasons for belly nosing in piglets that are separated from the sow have not been definitively established. However, it has been proposed that this behaviour represents a continuation or redirection of the sucking behaviour observed in piglets. It is believed that piglets engage in belly nosing as a response to unfamiliar feed during intermittent suckling. It has been suggested that if piglets fail to adapt to or compete for the creep feed, they may resort to alternative behaviours, such as manipulating other piglets.

5.2.6 Growth Performance of Lactating Sows Subjected to Different Durations of Separation from the Piglets

Intermittent suckling has been reported to reduce weight in lactating sows (Kuller *et al*, 2004; Diana *et al*., 2016). In this study, the weight loss in sows in 0 and 4 hours of separation from their piglets were significantly higher than that of those in 8 and 12 hours of separation. As earlier explained, sows are often catabolic and loses weight during lactation because their feed intake is not always sufficient to meet up with the nutrient requirement for milk production. Therefore, the sow mobilizes the tissue reserves in order to meet up thereby losing weight. However, the period of separation in this experiment reduced suckling by the piglets which in turn leads to reduction in milk production and weight loss in the sows. This is in agreement with the results of Kuller *et al*. (2004) and Diana *et al*. (2016) who reported lower body weight loss in sows subjected to Intermittent suckling compared to those on continuous suckling.

5.2.7 Luteinizing Hormone, Follicle Stimulating Hormone and Oestrogen Concentrations in Sows from the Period of Intermittent Suckling to the Onset of Oestrus

Lactating sows are often anoestrus. The suckling stimulus from the piglets sends a negative feedback to the hypothalamus thereby inhibiting GnRH secretion. However, for every time the piglets are separated from the sow, there is a positive feedback to the hypothalamus which secretes GnRH. GnRH stimulates the pituitary gland to secret gonadotropins (luteinizing hormone and follicle stimulating hormone) (Knox and Wilson, 2007). However, once the sow is returned to the piglets, the suckling stimulus pauses the secretion of LH and FSH but there is already a level of these hormones in the blood. As piglets are being separated from the sow, the level of the hormones keep increasing, which could initiate ovarian activity, follicular development, as well as oestrogen secretion, and this leads to a reduction in the number of days required for these hormones to get to their peak thereby reducing the weaning to oestrus interval. In this study, the increasing hours of separation led to a gradual increase in the LH concentration and this reduced the weaning to oestrus interval. The presence of FSH and LH initiates the follicle growth and maturation during the post-weaning period. Growing follicles secrets oestrogen which leads to rising plasma concentration of oestrogen (estradiol-17β) level in the blood. The rising plasma concentration of oestrogen (estradiol-17β) gets to a threshold that causes a pre-ovulatory surge in LH secretion at oestrus. Once there is a surge in LH secretion, the oestrogen level starts decreasing (Knox and Wilson, 2007).

5.3 Duration of Intermittent Suckling on Weanling Pigs Growth, Behaviour, Stress Response and Subsequent Reproductive Performance of the Dam

5.3.1 Growth Performance of Weanling Pigs after Intermittent Suckling

The weaned pigs that were separated for 12 and 8 hours during lactation that had a significantly higher feed intake compared to those that were separated for 4 and 0 hours and this reflected in their weight gain in which they had a significantly higher weight gain compared to those that were separated for 0 and 4 hours. The increased weight gain observed after weaning helped to offset the negative impacts of intermittent suckling (IS) on weight gain during lactation, which resulted in lower weaning weights for litters subjected to IS. The growth suppression experienced during lactation due to intermittent suckling aligns with findings from previous research (Thompson *et al*., 1981; Henderson and Hughes, 1984), although other studies did not find any effects on weight gain (Newton *et al*., 1987). Also, weaning ends access to suckling milk from the sow. However, intake of a solid diet by the weanling pigs can be delayed for up to 48 hours depending on the severity of the weaning stress on the animals (Bruininx *et al*., 2002). The delay in the intake of solid feed leads to a decrease in nutrient delivery to the small intestine, resulting in the shrinking of small intestinal villi and a decline in their ability to absorb nutrients (Marion *et al.*, 2002). However, weanling pigs subjected to intermittent suckling started eating almost immediately they were weaned. This could be as a result of a more developed gut of the weanling pigs subjected to intermittent suckling to handle solid feed due to the period of separation and early exposure to feed. This is in agreement with results of Kuller *et al.* (2004) and Diana *et al*. (2016) who reported that weanling pigs earlier subjected to intermittent suckling had higher feed intake and weight gain when compared to those that were on continuous suckling. Nabuurs *et al*. (1996) demonstrated that providing creep feed during lactation, along with intermittent suckling, partially averts the typical reduction in villus height and uptake in the small intestine that occurs after weaning. As a result, intermittent suckling may contribute to a healthier gut in piglets after weaning by promoting increased intake of creep feed during and after lactation, and potentially reducing stress at the time of weaning. This could potentially decrease the risk of post-weaning diarrhoea and improve the performance of weanling pigs. However, in this particular experiment, the impact of intermittent suckling on post-weaning diarrhoea could not be assessed due to the absence of such cases.

The reduced weaning weights observed in weanling pigs subjected to intermittent suckling in this study did not have a negative effect on post-weaning growth. It appears that post-weaning growth is influenced more by the piglets' ability to adapt to solid feed other than their weight at weaning. The weight gain and feed intake of the litters post-weaning were positively associated with the intake of creep feed during lactation. Interestingly, the beneficial effects of intermittent suckling on the growth and feed intake of weanling pigs after weaning were not solely dependent on increased creep feed intake during lactation. It is possible that weanling pigs subjected to intermittent suckling perceived weaning as a less stressful event because they were already accustomed to separation from the sow.

5.3.2 Corticosterone Concentration in Weanling Pigs after Intermittent Suckling

In this study, serum corticosterone was used as physiological indicator of stress. According to Moberg and Mench (2000), stress is a biological response that occurs when an organism senses a threat to its internal balance. It arises when an animal is not able to cope with a challenge either physiologically or behaviourally. Therefore, when investigating the potential effects of weaning on the welfare of weanling pigs, it is crucial to identify instances where the animals are unable to cope with the challenge in terms of their physiological or behavioural responses (Moberg and Mench, 2000). This refers to situations where there is a biological cost to the animals (Hemsworth *et al*., 2014). In response to stressful situations, the elevation of corticosterone levels in the bloodstream is an adaptive mechanism of the organism to adapt to a changing environment (Jarvis *et al*., 2006).

In this study, the corticosterone concentration (ng/ml) of weanling pigs earlier subjected to intermittent suckling was measured. The weanling pigs that were not separated from their dam during lactation were more stressed after weaning compared to other treatments. This may be due to the fact that the weaning process was more sudden on the animals compared to other treatments as reflected by the corticosterone concentration in their blood. The increased corticosterone level may be attributed to the stress of weaning which was caused by sudden maternal separation and complete change in nutrient source i.e from milk to solid feed. Mason *et al*. (2003) reported that corticosterone, a physiological response of stress was higher in weanling pigs that consumed little or no creep feed before weaning. Campbell *et al*. (2013) reported that the removal of sow milk and environment changes led to a drastic reduction in feed intake which was caused by loss of appetite (anorexia). Overnight maternal separation has also been found to be related with elevated basal corticosterone concentration in newly weaned pigs (Klemcke and Pond, 1991).

5.3.3 White Blood Cell Count and Its Differentials in Weanling Pigs after Intermittent Suckling

White blood cell count was also used as physiological indicator of stress in this study. Haematological parameters such as white blood cell count are good indicators of physiological and pathological changes in animals (Adenkola and Durotoye, 2004). In this study, the white blood cell count of the weanling pigs that were not separated from their dam during lactation was significantly higher than the other treatments. In other words, there was a significant reduction in the white blood cell count with increasing hours of separation**.** The higher white blood cell counts in weanling pigs that were not separated from their dam during lactation can be attributed to the stress caused by maternal separation and the transition in feed source from the sow (Buckham-Sporer *et al*., 2008). This stress leads to the release of white blood cells from their reserve into the peripheral circulation, potentially due to their inhibitory effect on circulating corticosterone, which is known to increase during periods of stress (Adenkola *et al*., 2009). However, it should be noted that the mean white blood cell count values obtained in this study were within the reference range reported by Mitruka and Rawnsley (1977).

Neutrophil:lymphocyte ratio (N:L) is one of the useful stress indicator is the changes in WBC differential counts. In this experiment, there was no particular trend in the lymphocyte and neutrophil count of the weanling pig making it difficult to draw firm conclusions. However, as glucocorticoid concentration increases, lymphocyte numbers tend to decrease whereas number of neutrophils tends to increase. Neutrophils are the first line of defence in an organism's immune system. When there is a threat to the immune system of an organism, the neutrophils are more produced due to their anti-inflammatory activities and the destruction of infiltrating micro-organisms.

5.3.4 Feeding and Aggressive Behaviour of Weanling Pigs after Intermittent Suckling

The result of this study showed that weanling pigs that were on continuous suckling during lactation spent lesser time feeding for some days after weaning than those that were earlier subjected to intermittent suckling during lactation for 4, 8 and 12 hours. This may be due to depression caused by sudden maternal separation and changes in nutrition source. However, the time spent feeding for the weanling pigs on earlier subjected to continuous suckling gradually increased as days pass. This is in agreement with the findings of Berkeveld *et al*. (2007) who reported increased feeding behaviour in weanling pigs earlier subjected to intermittent suckling at the lactation stage. Also, weanling pigs on continuous suckling were more aggressive than those on varying hours of separation during the lactation stage and this may be due to depression caused by sudden maternal separation. However, the aggresiveness gradually reduced as days pass. This agrees with the findings of Berkeveld *et al*. (2007) who reported higher aggressive behaviour in weaned pigs not subjected to intermittent suckling at the lactation stage.

5.3.5 Manipulative Behaviour of Weanling Pigs after Intermittent Suckling

Behaviours involving manipulation, such as belly nosing and interacting with pen or littermates, can indicate distress in piglets (Dybkjaer, 1992). In this study, weanling pigs that were not subjected to intermittent suckling expressed the highest level of manipulative behaviour when compared with those earlier subjected to intermittent suckling suggesting that intermittent suckling is a way of eliminating manipulative behaviours such as belly nosing, nosing, and tail biting and so on, in weanling pigs. Belly nosing, nosing and tail biting are some of the manipulative behaviour often seen in weanling pigs, especially those weaned at an early age (Worobec *et al.,* 1999). The specific cause of belly nosing is yet to be determined, but it has been proposed that this behaviour represents the persistence or redirection of sucking behaviour in piglets that have been separated from the sow (Dybkjaer, 1992). Belly nosing is not observed in piglets that are naturally weaned (Jensen, 1995). Also, weaning piglets at a later age significantly reduces the occurrence of this behaviour (Worobec *et al*., 1999). The inclination for belly nosing may also be associated with how piglets respond to unfamiliar feed after weaning. It has been suggested that difficulties in adapting to or competing for creep feed may prompt piglets to adopt alternative responses, such as manipulating other piglets.

5.3.6 Reproductive Performance of Weaned Sows after Intermittent Suckling

Intermittent suckling is only acceptable if sow reproductive performance is not negatively affected. Consequently, this experiment also investigated the impact of intermittent suckling on sow reproductive performance. The body condition of a sow determines how soon it will return back to oestrus after weaning. The more the weight loss during lactation, the more time it takes the sow to return back to oestrus and vice versa. This was evident from the result of this experiment as it took sows on T1 an average of 7 days to return back oestrus after weaning compared to 3 days in sows in T4. Oestrus was advanced by intermittent suckling resulting into shortened weaning to oestrus interval. This might have been due to reduced milk production and decreased weight loss in sows subjected to intermittent suckling, resulting in lower piglet weight gain. Piglet weight gain is closely associated with milk nutrient production (Noblet and Etienne, 1989). Foxcroft (1992) indicated that sow reproductive performance is influenced by the sow's metabolic state and the suckling stimulus from piglets. During lactation, sows often experience a catabolic state, which can lead to suboptimal reproductive outcomes after weaning (Foxcroft *et al.*, 1996). This aligns with the findings of Kuller *et al*. (2004), who reported a shorter weaning-to-oestrus interval in sows subjected to intermittent suckling.

5.4 Summary of Findings

Weaning piglets at 6 weeks reduced the severity of weaning stress on their growth and behaviour. Feed intake and weight gain was lower in pigs weaned at four weeks while aggressive behaviour was higher for the first few days post-weaning. Weaning piglets at 6 weeks reduced the excessive lactational weight loss in sows thereby making them to be ready for mating as soon as possible.

Piglets subjected to intermittent suckling had a lower weaning weight as the duration of separation increased. Corticosterone level was high in piglets subjected to intermittent suckling. Creep feed intake of piglets subjected to intermittent suckling was higher as the duration of separation increased. There was higher weight loss in sows not subjected to intermittent suckling.

The weanling pigs earlier subjected to intermittent suckling had superior weight gain and feed intake in accordance with the increasing duration of separation. The weanling pigs that were not subjected to intermittent suckling had higher corticosterone level after weaning which shows that they were more stressed compared to the weaned pigs earlier subjected to Intermittent suckling. Feed intake was lower in weanling pigs not subjected to intermittent suckling for the first few days after weaning while aggressive behaviour was higher for the first few days after weaning. Weaning to oestrus interval of the sows reduced according to the increasing duration of separation.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary and Conclusion

The assessment of different weaning times on weanling pigs' growth, behaviour, stress response, and subsequent reproductive performance of the dam is a complex and multifaceted process. Balancing the benefits of early weaning in terms of piglet growth with the advantages of delayed weaning in relation to behaviour, stress, and reproductive performance is essential for maximising overall swine productivity and welfare. Ongoing research and practical experimentation in this area will continue to refine our understanding of the optimal weaning strategies for different production systems, ultimately benefiting both producers and the pigs they raise.

Also, the evaluation of durations of intermittent suckling on piglets and weanling pigs' growth, behaviour, stress response, and subsequent reproductive performance of the dam provides valuable insights into swine management strategies. Implementing appropriate durations of intermittent suckling can contribute to improved weanling pigs' growth, behaviour, stress management, and overall reproductive performance of the dam. Ongoing research, collaboration, and knowledge exchange between producers and researchers will continue to enhance our understanding of the optimal intermittent suckling protocols, ultimately benefiting the productivity, efficiency, and welfare of swine production systems.

6.2 Recommendations

This research established 6 weeks as the optimum weaning time for piglets as this will reduce the compromise on their welfare due to weaning. Also, it will reduce the excessive weight loss in sows during lactation due to longer lactation length. It is also recommended to farmers to consider 8 hours of separating piglets from their dam starting from the fifth week of lactation till the end of lactation as this will further help in eliminating or minimizing behaviours that indicate compromised welfare in weanling pigs. Also, it will further help the sows in reducing weight loss during lactation thereby encouraging quick rebreeding of the sows as soon as possible after weaning.

6.3 Contributions to Knowledge

(1) Six weeks was revealed to be the optimum weaning time for piglets to be weaned from their dam.

(2) Intermittent suckling caused a reduction in the weight gain of the piglets according to the increasing duration of separation.

(3) Weanling pigs earlier subjected to intermittent suckling had a better feed intake and weight gain.

(4) Eight hours of separation was established as the optimum duration of separation of piglets from their dam because it led to better weight gain and feed intake of the weanling pigs.

(5) Eight hours of separation was also established as the optimum duration of separation of piglets from their dam because it reduced weaning to oestrus interval and weight loss of the dam.

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