OBSERVATIONS AND CONSIDERATIONS WHEN ARTIFICIALLY REARING BABY PIGS IN A NON-ISOLATED ENVIRONMENT

by

KATHLEEN ANN MORIARTY

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Approved by:

Gary Allee
Major Professor

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INTRODUCTION

The baby pig, when sow-reared, has a high rate of mortality; the majority of factors which cause, or lead to, this high death loss can be avoided by artificial rearing of the pigs. However, the piglet has several special requirements which must be considered when designing an artificial rearing program.

PRE-WEANING MORTALITY

Estimates of Mortality

Many researchers have estimated that 20-30% of all pigs farrowed die before weaning (Pomeroy, 1960a; Kernkamp, 1965; Rodeffer et al., 1975; Fahmy ane Bernard, 1971; Nielsen et al., 1974; Menzies-Kitchin, 1937; Fredeen and Plank, 1963; Stanton and Mueller, 1977; England, Day and Fogg, 1976; Omtvedt et al., 1966; Bille et al., 1974a; Waldorf et al., 1957; Strang, 1970; Winters et al., 1947; Kerncamp, 1943; Bereskin et al., 1973) while only an additional 2-5% die in the period from weaning to market (Fahmy and Bernard, 1971; Bereskin et al., 1973). Mortality rate within litters are usually less than 20% although it can vary from 0-100%, the higher figure due primarily to disease. The pre-weaning death loss has almost as much influence on litter size at weaning as does the number of pigs farrowed (Perry and Rowell, 1969).

Although infertility problems are the primary reason for culling sows, approximately 17-22% are culled because of piglet mortality and poor or small litters, and an additional 6-10% are culled due to udder problems (Pomeroy, 1960a; Svendsen et al., 1975). In the perinatal period, 58% of all sows have a litter with losses (Bille et al., 1974a) and 51.9% lose a live-born pig (Mauer and Hafez, 1959). Scheel et al. (1977) reported the average number of deaths per litter to be 1.93.

Stillbirths account for approximately 2-6% of the loss (Kernkamp, 1965; DeRoth and Downie, 1976; Bille et al., 1976; Curtis, 1974; Fahmy and Bernard, 1971; Severson, 1925; Stanton and Mueller, 1977; Fredeen and Plank, 1963; Mauer and Hafez, 1959; Bille et al., 1974a; Randall, 1972). The wide variation in reported stillbirth estimates is partly due to difficulty in distinguishing a genuine stillbirth and pigs born alive but dead when the litter is first examined (Pomeroy, 1960b).

Of the pigs which die during the preweaning period, approximately 50% die the first week (Bille et al., 1974a; DeRoth and Downie, 1976; Fahmy and Bernard, 1971; Kernkamp, 1965; Hutchinson et al., 1954), although estimates may range as high as 88% (Bille, Nielsen and Svendsen, 1974b; Pomeroy, 1960b; Nielsen et al., 1974). Kerncamp (1965) reported the loss the first week to be 2.5 times greater than the accumulative death loss the following 7 weeks. Losses decline daily the first week and within each successive week (Kerncamp, 1965; Severson, 1925), with as few as 1% of the fatalities occurring after the third week (Stanton and Mueller, 1977). The most critical period is the first 3 days when the pig is most vulnerable to adverse environmental conditions; 50-70% of the total loss has been reported as occurring these crucial 3 days (Pomeroy, 1960b; Nielsen et al., 1974; Fahmy and Bernard, 1971; Bille et al., 1974a, 1972; DeRoth and Downie, 1976). The first day is the most critical and approximately one-third of the first week's losses occur then (Fahmy and Bernard, 1971; Bille et al., 1974a, 1976; Kerncamp, 1965; Pomeroy, 1960b; Bertsch et al., 1976; Bourne, 1969b; Randal, 1973). Bille et al. (1976) reported that 86.4% of all pigs born alive and dying the first 3 days are the victims of noninfectious causes; these pigs are the ones which could most likely be saved through artificial rearing.

Factors Influencing Mortality Rate

There are many factors which have an influence on how high the mortality is for an individual herd. Sow herds vary not only in mortality rate (Bille et al., 1974a; Kerncamp, 1965, 1943; Nielsen et al., 1974) but also in how large an influence each causative factor has on the rate (Nielsen et al., 1974).

Type of housing and degree to which farrowings are attended are major factors in causing variation in mortality rates among herds (Bille et al., 1974a). Mortality rate increases with post-parturient disease of the sow (Bille et al., 1976) and amount of inbreeding (Severson, 1925; Pomeroy, 1960b; Fahmy and Bernard, 1971); breed and line also may influence the mortality rate (Fahmy and Bernard, 1971). Season of the year also significantly influences mortality rate, with the highest death loss during cold months (Pomeroy, 1960b; Nielsen et al., 1974; Bille et al., 1974a). Mortality increases with age of the dam (Bille et al., 1974a, 1976; Fahmy and Bernard, 1971; Nielsen et al., 1974; English and Smith, 1975; Kerncamp, 1965), with gilt litters generally being both smaller and lighter than mature-sow litters. This is most likely due to heavier sows being more likely to crush piglets as well as an interaction with increased litter size and decreased birth weight of individual pigs (Lush et al., 1934; Bille et al., 1974a, 1976; Scheel et al., 1977; Menzies-Kitchin, 1937; Stanton and Mueller, 1977; DeRoth and Downie, 1976; Revelle and Robison, 1973; Winters et al., 1947).

Litter size at birth exerts the most pronounced direct influence on mortality rate of all the contributory factors. Lodge et al. (1961) reported a positive correlation between mortality and litter size. Mortality rates are fairly constant for litters of 5-13 pigs at birth but increase sharply in exceedingly small and large litters outside this range, with large litters experiencing as high as 50% mortality (Bille et al., 1976; English and Smith, 1975; Pomeroy, 1960a; Severson, 1925; Wilson et al., 1974a; Menzies-Kitchin, 1937; Nielsen et al., 1974; Bille et al., 1974a; Fahmy and Bernard, 1971; Winters et al., 1947). In litters of fewer than 4 pigs at birth, mortality tends to be either 0% or 100%, depending mainly on the sow's temperament and how well the small number of pigs can maintain an adequate milk flow (Pomeroy, 1960a). With the small litters, % mortality can be misleading since an individual pig is such a large percentage of the total litter. Wilson et al. (1961) reported the optimum litter size to be between 11 and 14 pigs at birth for both optimum number weaned and litter weight at weaning.

Ahlschwede and Robison (1965) reported that 17% of Durocs and 8% of Yorkshire sows farrowed more live pigs than had functional nipples and in extremely large litters the herdsman may deliberately kill the small and weak piglets which are surplus to the sow's number of functional teats in order to help give the stronger pigs a better chance at survival. Some authors reccomend killing all runts, those pigs less than approximately 1.5# (Anon., 1977; Menzies-Kitchin, 1937). Pomeroy (1960a) reported that there is little to be gained by breeding for fertility in excess of 12-13 pigs per litter because of the limited number of functional teats and rapid increases in mortality in litters larger than this. He suggested that in the extremely large litters the increased mortality is not due simply to starvation of surplus pigs since the ultimate number of pigs weaned may actually be fewer than the number of functional teats the dam has, and proposed that the high death rate is related to the inverse relationship between litter size and individual pig birth weights. DeRoth and Downie (1976) reported a decrease in piglet viability scores with an increase in litter size.

Except in extremely large litters, although there is an increase in mortality with increased litter size, the ultimate number of pigs weaned per litter is higher (Nielsen et al., 1974; Severson, 1925). Under ordinary management conditions, assuming an average death loss of 1-2 pigs per litter (Scheel et al., 1977; Menzies-Kitchin, 1937; Nielsen et al., 1974; Rodeffer et al., 1975; Krehfiel et al., 1968), there is no advantage of the litter size at birth exceeding the number of functional teats on a sow by 1-2 pigs.

Major Causes of Mortality

Edwards (1972) reviewed the many causes of the high prenatal and perinatal mortality in pigs. Often vague categories are listed or a high percentage are listed in a "miscellaneous" or "unknown" category. Studies vary widely not only in listed causes but also percentage of deaths attributed to each, probably because of the complex interaction of causes.

Some factors may be considered as the primary cause of death while others are only secondary. English and Smith (1975) estimated that in only 32.6% of the cases examined was the piglet death attributable to a single factor; Two or more factors usually acted in a chronological sequence with the initial factor probably the most important since it acts as the catalyst. Kerncamp (1943) reported pre-weaning mortality to be attributable to more than 35 different diseases, disorders or conditions. Smith (1972) reported 82 factors, acting singly or in combination, contributing to the death sequence and categorized them into 5 main groups. He proposed that the single most important factor which triggered the death sequence was the inability of the pig to achieve a regular suckle. English and Smith (1975) also delineated 5 groups of primary factors which contribute to 88.2% of the deaths.

In general, the 5 main major groupings of causes of neonatal mortality appear to be: stillbirths; crushing or trauma; starvation; gastro-intestinal diseases; and undersized. In most studies a large proportion of deaths are attributed to crushing, overlay by the sow or fatal traumatic lesions (Rodeffer et al., 1975; English and Smith, 1975; Fahmy and Bernard, 1971; Bille et al., 1972, 1974a,b; Nielsen et al., 1974; Hutchinson et al., 1954). However it is most likely that at least a proportion of these deaths had other factors, especially starvation, acting as the primary factor, predisposing the pig to crushing; an aggregate of crushing and starvation figures is usually very high in all studies.

Birth Weight: The single most important factor in neonatal pig mortality is individual birth weight. An increase in litter size may cause lower birth weights by increasing the intensity of competition by feti within a uterine horn (Dyck, 1977), not because they are farrowed earlier. The location of the fetus in the uterine horn during gestation also affects a pig's birth weight (Dyck, 1977; Waldorf et al., 1957; Perry and Rowell, 1969; Dziuk and Hentzel, 1977). Dziuk and Hentzel (1977) reported an increased incidence of runts as there was an increased number of fetuses in each uterine horn.

A lower than average birth weight may act as a catalyst to many other factors contributing to the death of a small pig, or lead to a series of social effects which may contribute to an already disadvantaged pig (McBride et al., 1964). Many researchers have noted the increased mortality among pigs of lower than average birth weight (Scheel et al., 1977; England et al., 1976; McBride et al., 1964; Pomeroy, 1960b; English and Smith, 1975; Fahmy and Bernard, 1971; Lodge et al., 1961; Hartsock and Graves, 1970, 1976; Bustad et al., 1948; Bille et al., 1974a; Bereskin et al., 1973; DeRoth and Downie, 1976; Pettigrew, Zimmerman and Ewan, 1971). England et al. (1976) reported that 20% of the pigs farrowed are in the critical weight range of less than 2.0#. Bille et al. (1974a) reported that 1.3% of the liveborn pigs could be classified as undersized (less than 900 grams) yet represented 9.4% of the perinatal mortality. They also reported that 11.6% of the litters observed had at least 1 undersized pig, and the majority of affected litters had only one pig classified as undersized. Bille et al. (1972) and Svendsen et al. (1975) also reported that while runts represent 1.3% of all live pigs at birth, they account for 9.4% of perinatal deaths and 5.5% of the total pre-weaning mortality. Hartsock and Graves (1970) reported that the lightweight pigs were slower to establish a permanent nursing position and had a lower rate of gain the first 21 days as compared to their heavier littermates.

DeRoth and Downie (1976) developed a system of establishing a viability score for newborn piglets; there was a strong positive correlation of viability score with birth weight. Low scorers were less active and robust and were more likely to be killed by the sow; they often made no attempt to nurse or held onto a teat without actually suckling; they were unable to defend a teat, were crowded out and eventually died. Lush et al. (1934) reported that in a large group of pigs classed on the basis of vigor and condition, there was not much variation in birth weight among pigs within a class. Sows usually take an interest in their litters as long as some pigs are noisy and active, which seems to aid in stimulating the sows' maternal instincts (Pomeroy, 1960b). Sows usually ignor dead, comatose or apathetic pigs, thus these are more likely to be crushed (Pomeroy, 1960b; English and Smith, 1975).

Weakness in the piglet may contribute to starvation and/or inadequate nutrition, chilling, crushing and infection. The pig must be strong enough to massage the dam's mammary gland to stimulate the flow of milk (Donald, 1937b), and Hartman and Pond (1960) reported that massaging may increase milk yeilds approximately 10%. The ultimate measure of vigor is the piglet's survival and growth rate, and these reflect how well the pig has been able to adapt to and tolerate its new environment.

The runt pig is not simply a miniature replica of its larger littermates. Pomeroy's (1960c) studies revealed that the runt pig tended to have a relatively larger surface area than its littermates. This, combined with a disproportionately smaller musculature with which to generate heat to keep warm, plus relatively smaller glycogen reserves in the muscles, as well as being weaker, handicaps the runt in competition for survival. Pomeroy (1960b) also reported that the late-developing parts (muscles) are retarded to a greater extent than early-developing parts (Brain, organs, skeleton). Thus it appears that the runt could survive if given an environment in which it did not have to compete.

The proposal that perhaps the undersized pig is physiologically immature is not well supported in the literature. DeRoth and Downie (1976) indicated that all newborn pigs, in comparison to other species, are physiologically underdeveloped and propose that this contributes to the high mortality the first 10 days of life. Bille et al. (1974a) reported no tendencey for preterminally born baby pigs to be classified as undersized. Pomeroy (1969b,c) found little evidence to support the theory that the undersized pig may be physiologically immature, since it is not equivalent to a fetus of the same weight. Curtis, Heidenreich and Martin (1967) concluded that birth weight is not positively associated with the developmental maturity of the piglet.

Weight Variation Within the Litter: Disparity in size of pigs within a litter can increase the difficulty the smaller piglets have in pushing their way to the udder and obtaining a teat in time to get the full benefit of the milk letdown. England et al. (1976) reported that survival was negatively associated with within-litter variation in birth weight.

English and Smith (1975) reported that the overall mortality of smaller than average piglets was significantly less in litters with little variation in birth weights; the lowest mortality of liveborn pigs occurred in litters with high average birth weights and low variation in birth weights. Their data also indicated that high average birth weight is not necessarily adventageous for pig survival unless there is also uniformity of birth weights within the litter. Fahmy and Bernard (1971) also reported a significant linear relationship between survival to weaning and within-litter coefficient of variation of pig birth weight. Menzies-Kitchin (1937) reported that the death rate post-weaning was also greatest for pigs from litters with the largest variation in individual pig weights at 6 weeks of age. Thus pigs have the best chance for survival if there is little inequality of birth weights within the litter, since the lightest pigs will be disadvantaged regardless of their birth weight.

<u>Crushing/Trauma</u>: The proportion of preweaning mortalities attributed to trauma, especially overlay by the sow, is extremely high. Bille <u>et al</u>. (1974b) reported trauma to be a primary cause of death and accounts for 18.3% of the total loss, with nearly 6% of all liveborn pigs suffering fatal traumatic lesions before weaning. They also reported that 34% of all litters have a fatality attributed to trauma. In a survey of U.S. hog producers, 20% consider crushing of baby pigs to be one of the 2 worst problems in the farrowing house (Anon., 1975).

Bille <u>et al</u>. (1974b) reported that litter size at birth and illness of the sow were the most important influences on how many pigs are crushed. The highest incidence occurred in sows with MMA or other diseases resulting in hypo- or agalactia. Apparently the hungry pigs attempting to nurse increase the pain of the infected udder and cause the aggitated sow to attack her young. The sow is also less alert and mobile, and the pigs are constantly moving around her attempting to nurse. Bille <u>et al</u>. (1974b) also reported that trauma is the most important cause of death the first 3 days and most of the deaths attributed to trauma occur the first 24 hours. Jones (1966) reported that crushing most commonly occurs after all pigs have been born and the sow stands and lays down again for the first time.

Bille <u>et al</u>. (1974b) reported a higher proportion of traumatized pigs in large litters; apparently the risk is increased as more hungry pigs congregate around the sow competing for the limited milk supply. Bille <u>et al</u>. (1974a,b) also reported various factors which predispose the pigs to crushing as being: low birth weight; starvation; weakness; septicemia; gastro-intestinal diseases; and malformations, such as splay-legs.

<u>Gastroenteritis</u>: Diseases, except in epidemics, do not account for a large percentage of the incipient causes of mortality in baby pigs. The pathogenic microorganism-caused disease may be only the immediate cause of death and another factor, such as starvation or trauma, predisposes the pig to infection. Of the

diseases, however, those of the alimentary tract are the most important (Nielsen _et al._, 1974; Svendsen _et al._, 1975; Mitchal _et al._, 1968).

Mortality due to gastro-intestinal disorders is higher in litters where the sow suffers MMA of other post-parturient diseases (English and Smith, 1975), probably due to an inadequate supply of colostral and milk antibodies; this could also account for the higher incidence in large litters where the number of pigs exceeds the number of functional teats.

Bacterial Septicemia: Nielsen _et al._ (1975) reported that 12.3% of preweaning deaths can be attributed to bacterial septicemia, with the dam as the main source of infection, and the majority of deaths occurred the first week. They theorized that there was a higher incidence in gilt litters due to less resistance being transferred to the piglets; the higher incidence in large litters and those where the dam is afflicted with post-parturient diseases such as MMA may be due to insufficient colostral antibodies. Bille _et al._ (1974a) reported bacterial septicemia to be a contributing factor in the deaths of undersized and debilitated pigs.

Anoxia: Many researchers have indicated that the majority of stillbirths are due to prolonged hypoxia during parturition (DeRoth and Downie, 1976; Randall and Penny, 1968; Randall, 1973; Bille _et al._, 1974a; Calder _et al._, 1959; English and Smith, 1975). With liveborn pigs, anoxia may cause decreased viability and have an adverse effect for several hours on the pig's ability to cope with its new environment (English and Smith, 1975; Fahmy and Bernard, 1971; Randall, 1971, 1972, 1973; Randall and Penny, 1968). Calder _et al._ (1959) reported that runts tended to have elevated blood glucose and lactose levels, indicating hypoxia during the birth process, and had reduced survival rates.

Anoxia may cause mobilization and metabolism of the piglet's limited glycogen and carbohydrate reserves, thus causing a further disadvantage to the newborn; anoxia may also cause depression of the central nervous system as well as thermoregulatory centers. The anoxia results in the pig being born lethargic, comatose or disorientated, and such a pig is unable to compete with its littermates and is more likely to be crushed by the sow.

Starvation: English and Smith (1975) reported that starvation contributed to nearly one-half of the preweaning deaths, and a survey of producers (Anon, 1975) revealed that 25% of those polled felt that starvation of piglets is one of the two worst problems in the farrowing house. Some researchers report only a low percentage of mortality attributed to starvation (Bille et al, 1974a; Nielsen et al., 1974; Rodeffer et al., 1975; Svendsen et al., 1975) while in other reports the starvation is quite high (Fahmy and Bernard, 1971; Hutchinson et al., 1954). The discrepancy is probably due to the starved piglet being more susceptible to death from other causes.

Obviously starvation occurs when agalactia strikes the sow. But some pigs may not acheive an adequate regular suckle, even when the sow has milk available, if the sow is unwilling to allow her young to nurse or when the pigs, especially small, weak ones, are dispossessed of a teat as commonly occurs in large litters where there are more pigs than functional teats. The incidence of starvation is higher in large litters (Bille et al., 1976) and in pigs of lowest birth weight (Bille et al., 1974a; English and Smith, 1975).

There is a critical energy balence in the newborn pig (Holub, 1972a). It is essentially dependent on carbohydrate stores, limited lipid reserves and feed intake. While carbohydrates provide most of the energy for the starving newborn pig (Mount, 1966b; McCance and Widdowson, 1959), it is not exclusively dependent on carbohydrates for energy metabolism (Mount, 1969). Mersmann (1974) reviewed the literature concerning the 4 major metabolic defects in the neonatal pig and listed them as: low level of phosphorylase, potentially decreasing the rate of production of glucose from glycogen stores; defective gluconeogenic capacity; deficient hepatic mitochondrial number which limits the use of carbohydrates and fatty acids for energy production; small amount of body fat, impairing insulation and limiting energy reserves.

The neonatal pig is born with a large ability to carry on glycolysis (Mersmann, 1971; Curtis et al., 1966; Seerley and Poole, 1973; Stanton et al., 1973) and release glucose, utilizing both its liver and skeletal muscle reserves of glycogen (Curtis et al., 1966). However, the supply of glucose available for animals in a stressful situation is limited since gluconeogenesis is absent or minimally active in the newborn pig (Swiatek et al., 1968; Mason, Chao and Cornblath, 1968; Gentz et al., 1970; Carroll and Noland, 1973b; Mersmann, 1974; Stanton et al., 1973); it developes this ability by approximately 48 hours of age (Gentz et al., 1970; Mersmann, 1971, 1974; Mersmann et al., 1972). Gentz et al. (1970) calculated that available carbohydrate and fat stores would last about 72 hours but the pig may withstand starvation slightly longer because part of its caloric needs may be covered by catabolism of body protein.

Researchers report a significant increase in plasma glucose from birth to approximately 12 hours of age (Steele, Frobish and Young, 1970; Frobish, 1969a; Aherne et al., 1969b) probably due to the breakdown of glycogen. The pig utilizes the glucose as rapidly as it is produced (Andersona and Wahlstrom, 1970) and then there is a significant curvilinear decrease in plasma glucose level the next 36 hours (Aherne et al., 1969b; Gentz et al., 1970; Pettigrew, Zimmerman and Ewan, 1971) and can reach hypoglycemic levels within 72 hours in starved newborn pigs (Seerley and Poole, 1973, 1974; Swiatek et al., 1968). Pettigrew, Zimmerman and Ewan (1971) reported that the blood glucose level at 32 hours is positively correlated to performance. The pig becomes more tolerant to starvation and more resistant to hypoglycemia with age (Ahern et al., 1969a,b; Seerley and Poole, 1973, 1974; McDonald and Bayley, 1970; Mason, Chao and Cornblath, 1968; Goodwin, 1955, 1957) as it can better conserve glucose reserves and regulate metabolism.

At birth the pig has an appreciable store of energy reserves as carbohydrate (Morrill, 1952a). The liver and carcass glycogen content of the pig increase during late gestation (Mersmann, 1971; Mersmann et al., 1972; Okai et al., 1978) and are at very high levels at birth (Brooks et al., 1964; Curtis et al., 1966; Mason, Chao and Cornblath, 1968; Mersmann, 1971; Swiatek et al., 1968) with a relatively greater concentration of carbohydrate in the newborn pig compared to the older pig (Curtis et al., 1966). Glycogen is an important metabolic fuel for the neonatal pig, and liver and carcass levels fall rapidly after birth (Anderson and Wahlstrom, 1970; Curtis et al., 1966; Mason, Chao and Cornblath, 1968; Mersmann, 1971; Brooks et al., 1964; Morrill, 1952a; Seerley and Poole, 1973).

Lipids are mobilized and utilized for energy in the neonatal pig (Bertsch et al., 1976; Gentz et al., 1970) but the pig has a very low fat reserve at birth (Bertsch et al., 1976; Manners and McCrea, 1963b). Fat is rapidly deposited after birth (Bertsch et al., 1976; Brooks et al., 1964) with twice the carcass fat by 2 days of age and 8 times the amount at birth by 7 days of age (Manners and McCrea, 1963b).

The newborn pig has an under-developed ability to regulate its carbohydrate metabolism (Curtis et al., 1966) and cannot maintain its rectal temperature in cold stress (Curtis et al., 1966; Morrill, 1952d; Newland et al., 1949, 1952; Goodwin, 1955; Jensen, 1964) even though the circulating levels of sugars and compounds suitable for utilization in aerobic oxidative cycles were high (Curtis et al., 1966). This may be attributed to the newborn pig having a reduced rate of glucose assimilation as compared to older pigs (Curtis et al., 1966). The degree of rectal temperature decrease depends on the pig's size and environmental temperature, with the small pig's temperature decreasing faster

(Mount, 1960) and lower (Carroll and Noland, 1973a). Carroll and Noland (1973a, b) reported that runts were less able to maintain blood glucose levels than medium or large littermates at both birth and 19 days of age, and are poorer at energy conservation at birth.

When the neonatal pig is starved, hypoglycemic convulsions are apparent by approximately 39 hours of age although the time to develop severe hypoglycemia depends on age, environmental temperature and other factors (Goodwin, 1955). Newland et al. (1952) report that a pig which has received some feed is less susceptible to hypoglycemia than a pig which has been completely starved.

Goodwin (1955) theorized that runts, injured or surplus pigs in a large litter are especially susceptible to hypoglycemia, not necessarily due to complete starvation, but often to a progressively lower feed intake as they are less able to compete or cope with their environment. He reports a period of 3-4 days in which the blood glucose concentration is unstable and fluctuates with milk intake until the pig has developed the ability to conserve its energy reserves and established the capacity for gluconeogenesis.

Piglet Behavior

The neonatal pig's behavior also has an effect on mortality. The pigs establish a nursing order in which each identifies with a particular teat and tends to nurse only that teat. Before the teat order is established there is considerable fighting (McBride, 1963; Hartsock and Graves, 1976). The teat order allows nursing with a minimum expenditure of energy. The smallest pigs suffer the most from teat competition and win fewer fights, are slower to establish a permanent nursing position and may be starved out (Jones, 1966; Hartsock and Graves, 1976); they may not obtain milk each letdown period and have a high energy expenditure as they move from teat to teat, initiating more fights which are rarely won (Scheel et al., 1977). They attempt to suckle while the majority of the litter is sleeping (Jones, 1966), but milk letdown occurs only within a 35-45 second period each hour (Donald, 1937b).

The teat position is usually rapidly established. Hartsock and Graves (1970) reported that it is established within as few as 5 hours, and in all healthy litters by 40 hours; Nachreiner and Ginther (1974) reported it took 24 hours to establish, while Illyes et al. (1978) reported 62% of the pigs had selected a definite teat at approximately 81 hours of age and another 10% showed a clear preferance at that time. They also reported that nipple selection occurs earlier when there are more nipples available per pig. McBride (1963) observed that the beginning of the establishment of teat order could be seen within one hour of farrowing and even before the birth of the last pig. This is an important observation since heaviest pigs may be born first (Friend and Cunningham, 1966b; Hartsock and Graves, 1976).

The teat order is influenced by many factors; a less stable order occurs in large litters (Donald, 1937b), with inadequate milk supply (Donald, 1937b; Nachreiner and Ginther, 1974), poor maternal behavior in the sow (Donald, 1937b; McBride, 1963) and poor udder conformation of the sow (Donald, 1937b).

The anterior teats are actively preferred and are usually obtained by the largest pigs (Illyes et al., 1978; Wyeth and McBride, 1964a,b; Randall, 1972; Hacker et al., 1968; McBride, Wyeth and Hodgens, 1964; Allen and Lasley, 1958; Donald, 1937b; Nachreiner and Ginther, 1974; Scheel et al., 1977). The pigs nursing the anterior teats tend to make the largest gains (Donald, 1937b; Barber et al., 1955; Hartman and Pond, 1960), regardless of the birth weight (Barber et al., 1955). The anterior teats tend to be more productive (Barber et al., 1955; Donald, 1937a; Hartman and Pond, 1960), and there is a positive correlation between milk yeild and weight gain (Hartman and Pond, 1960). Nachreiner and Ginther (1974) reported that by the second day of age pig weight gains of those nursing the cranial teats are greater and by the third day they are much greater. Scheel et al. (1977) reported that the heavier pigs tend to be dominant, have lower mortality, and greater weight gains to 21 days of age. The high mortality of low weight pigs may not be solely due to an inability to compete for a favorable nursing position (Hacker et al., 1968; England et al., 1961), and some aspects of dominance, such as agility and aggressiveness, are independent of birth weight (Scheel et al., 1958). McBride et al. (1964) theorized that the teat order is especially important when the pig is dependent upon the milk supply, and heavier pigs have the advantages that they reach greater weights independently of teat position and tend to occupy the more productive teats. They calculated that birth weight and teat order account for 40% of the variation in 3-week weight within a litter. Hartsock and Graves (1976) observed that first-born pigs in a litter have a lower mortality, partly due to ingesting a greater proportion of the immunoglobulin-rich first colostrum and are heavier. They also noted that the smaller pigs win fewer fights for a teat and successfully suckle less frequently than larger littermates.

IMMUNITY TO DISEASE

Sow's Colostrum and Milk

In the pig, the dam's placenta is impermeable to not only foreign antigens, but also all immunoglobulins (Nelson, 1932; Kim et al., 1966c; Bengtsson, 1974; Sterzl et al., 1966) unless the placenta has been damaged or is defective (Myers and Segre, 1963). Thus passive immunity in pigs is transmitted principally by means of intestinal absorption of antibodies from the sow's colostrum or milk (Bengtsson, 1974; Earle, 1935; Lecce et al., 1962; Mason et al., 1930; Nelson, 1932; Ramirez et al., 1963; Brambell, 1958; Foster et al., 1951; Nordbring and Olsson, 1958a,b; Olsson, 1959b,c) although some antibodies may be ingested along with maternal fluids during the birth process (Kim et al., 1966c).

Immunoglobulins account for more than 60% of the colostral whey proteins (Porter et al., 1969). Sow colostrum is rich in immunoglobulins of all known classes (Kim et al., 1966c; Georgieva and Gerov, 1975; Porter, 1969; Porter et al., 1969) and the three major classes of immunoglobulin are IgG, IgA and IgM, which represent different functional groups needed to meet different types of antigenic responses (Fahey, 1970). For all classes of immunoglobulins, the concentration in sow milk whey is several times greater than normal porcine serum values during a period spanning the day before parturition to 3 days postpartum (Yabiki et al., 1974).

During the first week of lactation the immunoglobulin composition decreases to a level as low as one-fifth the original colostral level (Harrold and Johnson, 1976; Porter et al., 1969; Yabiki et al., 1974; Young and Underdahl, 1950) and the different classes of immunoglobulin differ in the manner of decrease (Yabiki et al., 1974). IgM and IgG decrease about 10-fold; IgA decreases about 2-fold, thus becoming the predominant immunoglobulin in sow milk after about the first 4 days of lactation (Porter and Allen, 1969; Porter et al., 1969). Yabiki et al. (1974) found no trace of IgG in sow milk whey after 2 weeks while IgA persisted at a level 3 times greater than normal sow serum levels.

Even within the first 24 hours after the birth of the first pig there is a drastic decrease in colostral whey protein (Bourne, 1969a; Martinsson, 1972) and as much as half of the decrease occurs within the first 4-6 hours (Bourne, 1969a). Coalson and Lecce (1973a) found the gammaglobulin content of the colostrum dropped rapidly with each ejection of the gland and if all pigs are prevented from suckling, the colostral whey protein levels do not change significantly during the first 4 hours from the start of parturition (Bourne, 1969b). Thus, to give all pigs an equal opportunity for the colostrum richest in immunoglobulins, all pigs must be caught at birth and then simultaneously placed on the sow. Coalson and Lecce (1973a) stated that pigs placed on the sow 4 hours after their littermates had less than half the serum gammaglobulin levels of their littermates, and 15% of these pigs had only 25% as much serum gammaglobulin. This may affect their viablility since gammaglobulin is the antibody-carrying protein.

IgM is promptly formed in response to antigen, and is rapidly catabolized with a half-life of approximately 5 days (Waldmann et al., 1970; Fahey, 1970); it has a high agglutinating efficiency and complement fixation capacity and is the main Ecoli antibody absorbed from colostrum (Porter et al., 1969). Of the 3 main classes of immunoglobulin it is present in the smallest quantities (Waldmann et al., 1970).

IgA is "secretory antibody" and is transported into saliva, tears, the urinary tract and the gastro-intestinal tract (Fahey, 1970) and it comprises a "local" immune system in the pig (Smith, 1971). It is very effective in resisting respiratory infections and is the second major class of Ig in sow colostrum (Porter, 1969). Many specific antibodies have been found in the secretory IgA fraction of colostrum, including antibodies against Ecoli (Porter and Allen, 1969), and their activity is well-suited to the pH and salt conditions of the gut (Smith, 1971); IgA survives intact through the intestinal tract better than any other class of Ig and it tends to adhere to the mucosal surface and resist absorption (Porter and Allen, 1969). It has a half-life of approximately 6 days (Waldmann et al., 1970).

IgG is the "blocking antibody" and seems to accumulate with repeated exposure to antigen (Smith, 1971). It is slowly catabolized, with a half-life of about 23 days (Waldmann et al., 1970). IgG is the main immunoglobulin class present in sow colostrum (Refnek et al., 1966; Bourne, 1969a), with approximately 80% of the Ig in sow colostral whey being IgG (Porter et al., 1969) although it decreases the first 48 hours of lactation to become a minor fraction of sow milk (Bourne, 1969a). Martinsson (1972) found a wide range of IgG levels among different sows; pigs from a sow with a low level may be hypo-gammaglobulinemic, and such pigs had twice as many infections as pigs from sows with normal levels.

At birth the baby pig is deficient in serum protein (Lecce and Matrone, 1960) and is born with no serum immunoglobulins (Asplund et al., 1962; Hajek and Mandel, 1971; Kim et al., 1966c, 1967; Kraehenbuhl and Campiche, 1969; Long et al., 1964; Prokesova et al., 1968; Young and Underdahl, 1950). Some researchers have found traces of antibodies in the pre-colostral piglet's serum, mainly in the gamma zone, but they possess no antibody activity (Bourne, 1974; Karlsson, 1969, 1970; Lecce et al., 1961a, 1962; Mount and Ingram, 1971; Myers and Segre, 1963; Payne and Marsh, 1962b; Porter, 1969; Porter and Kenworthy, 1979).

Absorption of Macromolecules

Some of the macromolecules Balconi and Lecce (1966) found in sow colostrum were gammaglobulins, a hormone with regulatory activity and an enzyme with catalytic activity (lactic dehydrogenase). Absorption of macromolecules occurs across the pig's intestinal mucosa primarily during the first few hours of life, generally agreed to be within the first 36 hours (Asplund et al., 1962; Blair, 1963; Brambell, 1958; Brown et al., 1961; Bourne, Kraehenbuhl and Campiche, 1969; Lecce and Matrone, 1960, 1961; Miller et al., 1962a; Morgan and Lecce, 1964; Mount and Ingram, 1971; Nordbring and Olsson, 1958a,b; Patt and Eberhart, 1976; Payne and Marsh, 1962b; Speer et al., 1959).

During this period, the pig's gut epithelial cells are qualitatively nonselective in their absorption via pinocytosis (Broughton and Lecce, 1970; Kraehenbuhl and Campich, 1969; Lecce, Matrone and Morgan, 1961a,b; Lecce and Matrone, 1961; Lecce, 1966a, 1972c; Mount and Ingram, 1971; Nordbring and Olsson, 1958a,b; Olsson, 1959a,b,c; Pierce and Smith, 1967a) and can absorb both homologous and heterologous gammaglobulins (Kim et al., 1966c; Lecce, Matrone and Morgan, 1961b; Payne and Marsh, 1962b) as well as potentially harmful macromolecules such as pathogenic organisms (Lecce, 1975). Even normally innocuous strains of Ecoli can pose a threat in the neonatal pig when its gut is still "open" (Lecce and Morgan, 1962; Lecce, Morgan and Matrone, 1964).

Ullrey, Long and Miller (1966) as well as Yabiki, Kashiwazaki and Namioka (1974) all proposed that the absorptive cells of the gut have specific receptors adapted to homologous molecules and the absorption of heterologous molecules varies according to how closely they resemble the homologous molecules. Many researchers have shown marked differences between absorption rates of individual proteins and macromolecules (Brambell et al., 1958; Lecce, 1966a; Pierce and Smith, 1967a,b; Sharpe, 1965; Yabiki et al., 1974). Kim, Bradley and Watson (1966c) found that within 5 hours the pigs absorb 90% of the homologous antibodies and 50% of the heterologous antibodies, while Payne and Marsh (1962b) found a predominant selectivity of the absorptive cells for gammaglobulin over other protein fractions of colostrum.

Apparently the protein molecules are absorbed in an unalterred form (Coalson and Lecce, 1971; Lecce and Matrone, 1961) since it has been demonstrated that intact antibodies are transferred into the circulatory system (Kraehenbuhl and Campiche, 1969), insulin is absorbed without affecting its role in carbohydrate metabolism (Asplund et al., 1962) and protein can be absorbed with retained enzymatic activity (Balconi and Lecce, 1966), which is important since some enzymes involved in metabolism of newborn pigs are present in sow colostrum (Balconi and Lecce, 1966).

The acquisition of passive immunity actually occurs in 2 phases (Clarke and Hardy, 1971; Lecce, 1973b); first the macromolecules in the gut lumen are taken up by the enterocytes and internalized via pinocytosis, then the macromolecules are transported into the blood and lymph (Broughton and Lecce, 1970; Kraehenbuhl and Campiche, 1969; Staley et al., 1968). Histological changes occur with age in the intestine (Comline et al., 1953); a vesicular and vacuoler apparatus develops after birth in the absorptive cells when they come in contact with colostrum or protein molecules (Kraehenbuhl and Campiche, 1969;

Sibalin and Bjorkmann, 1966) while the gut epithelium in the unsuckled piglet has few or no vacuoles (Kraehenbuhl and Campiche, 1969; Payne and Marsh, 1962b; Pierce and Smith, 1967b; Sibalin and Bjorkmann, 1966). The vacuoles which appear after suckling contain macromolecular material (Kaeberle and Segre, 1964; Payne and Marsh, 1962b), but these macromolecules absorbed by the intestinal epithelium do not necessarily appear in the bloodstream (Lecce, 1973a).

Originally, researchers only observed the appearance of macromolecules in the piglets' bloodstream and concluded that the significant antibody and immunoglobulin absorption ceases at approximately one day of age, after a logarithmic decline in the rate of absorption from birth (Miller _et al._, 1962a; Speer _et al._, 1959). Thus the efficiency of absorption rapidly falls (Kim _et al._, 1966c), and Speer _et al._ (1959) estimated the half-life of the efficiency of absorption to be approximately 3 hours.

However, research utilizing electron microscopy has shown that macromolecules continue to be absorbed after cells have stopped transporting them into the blood stream (Tlaskalova _et al._, 1970). Closure (cessation of pinocytosis) proceeds caudally along the small intestine (Clarke and Hardy, 1971; Leary and Lecce, 1976; Lecce, 1973b); duodenal enterocytes have the smallest capacity to internalize macromolecules, thus closing the soonest, while the ileum enterocytes remain open the longest and jejunum cells are intermediate (Leary and Lecce, 1976). The duodenum and uppper jejunum cease pinocytotic activity by 3 days of age while the lower jejunum and ileum remain open until 2 to 3 weeks of age (Lecce, 1973a,b); Lecce (1973b) noted that the loss of uptake activity in the upper small intestine was coincident with the loss in transport capacity along the entire small intestine. The plasmalemma may be able to form only a limited number of pinocytotic channels (Broughton and Lecce, 1970; Lecce, 1966a). Leary and Lecce (1976) theorized that the ileal enterocytes have more pinocytotic sites, or a greater capacity to regenerate these sites, than the duodenal enterocytes and hypothesized that the final closure as the pig approaches 23 days of age is probably due to a hormonal signal. Clark and Hardy (1971) observed that it is about this time that pigs show an interest in solid foods and wondered if it is just incidental.

Influences on Passive Immunity

The character of the diet may be of importance in influencing gut closure (Broughton and Lecce, 1970; Lecce and Matrone, 1960, 1961; Lecce and Morgan, 1962; Patt and Eberhart, 1976; Payne and Marsh, 1962b) since the rate of closure, but not the sequence, can be manipulated by the pig's dietary regimen (Leary and Lecce, 1976; Lecce, 1973b). Leary and Lecce (1976) hypothesized that certain diets may stimulate the use of pinocytotic sites on the plasmalemma of enterocytes.

Several researchers have related vesicle formation with the age of the pig (Sibalin and Bjorkmann, 1966; Staley *et al.*, 1968; Perry and Watson, 1967a). However the ability to absorb macromolecules may not actually be age dependent, but rather whether the pig has been fed and the amount of food consumed (Lecce and Morgan, 1962) and feed composition (Lecce, 1972c). Lecce (1966a) also reported that the capacity of the diet to affect closure is more dependent on the number of molecules rather than the kinds of molecules, and Pierce and Smith (1967b) indicated that the transfer of bovine lactoglobulin across the pig's gut is dependent on the amount or concentration of colostrum fed.

Starvation delays both uptake and transport of macromolecules (Lecce, 1966a, 1973b; Lecce and Morgan, 1962; Mount and Ingram, 1971; Payne and Marsh, 1962b) and Staley *et al.* (1968) stated that pigs starved for 42 hours after birth showed no appreciable change in morphology of jejunal absorptive cells. Closure may be accelerated in stressing dietary situations, such as being fed only 4 times per day, and in pigs with diarrhea (Lecce, 1966b, 1973b). Perry and Watson (1967a) also indicated that the rate of food passage may influence the quantity of gammaglobulin absorbed; they also reported that when the quantity of antibody absorbed is expressed in terms of dosage (efficiency of absorption), pigs fed the highest concentration absorbed only 2% of the available antibody vs. 13% at lower levels. Mount and Ingram (1971) reported that the efficiency with which bovine immune lactoglobulin is absorbed by the pig increases as the quantity fed increased up to 2 grams per day, thereafter the efficiency remained constant. They proposed that this is related to the saturation of proteolytic enzyme activity in the gut by larger doses so a larger proportion is absorbed intact.

Sow colostrum, milk and digesta hasten gut maturity, or closure (Broughton and Lecce, 1970; Leary and Lecce, 1976; Lecce et al., 1964), while a salt solution has no influence (Broughton and Lecce, 1970; Lecce et al., 1964). While some researchers report that a sugar solution induces closure (Broughton and Lecce, 1970; Lecce, 1966; Smith, 1971), Long et al. (1964) reported that pigs fed only a glucose solution for 2 weeks are still capable of absorbing gammaglobulins. Ullrey et al. (1966) reported that protein in the diet may influence the amount of intact protein absorbed but does not cause complete closure. Olsson's data (1959c) indicated that the amount of protein or gammaglobulin received influenced the ability to demonstrate these substances in the pig's serum but did not affect the pig's ability to absorb the immunoglobulin. Lecce et al. (1964) hypothesize that gut closure is influenced by a heat-stable, low molecular-weight protein in the protein- and fat-free fraction of colostrum and milk.

There are several other factors influencing the pig's ability to take up and transport macromolecules. Orally ingested antibodies can reach the small intestine intact due to the antitrypsin factor in colostrum retarding protein digestion (Nordbring and Olsson, 1958a,b; Ullrey et al., 1966), and a low level of proteinase activity in the digestive juices at birth (Ullrey et al., 1966;

Hartman et al., 1961; Braude et al., 1958) although Barrick et al. (1954) reported that an orally administered trypsinase inhibitor was of no benefit. Lecce and Mock (1973) reported a gradual change in the charge distribution on the microvilli of the gut cells and theorize that this may affect the kinds of macromolecules adsorbed to the cells.

Individual pigs vary widely in uptake of macromolecules (Clarke and Hardy, 1971; Perry and Watson, 1967a,b; Smith and Burton, 1972). The wide range of serum antibody levels at 12 hours of age indicate that the pigs are no longer of equal immune status at that time (Perry and Watson, 1967b) and pigs with high serum antibody titers have a greater survival rate and growth rate (Tlaskalova et al., 1970; Perry and Watson, 1967b). The variation occurs mainly among litters (Perry and Watson, 1967a,b; Mount and Ingram, 1971) and can be attributed to maternal effects associated with the variable secretion of agents in the colostrum, which not only occurs among sows but also varies among teats on an individual sow (Perry and Watson, 1967b); Buschmann (1972) demonstrated a genetic influence in relation to the serum antibody titer. Perry and Watson (1967b) reported a lack of correlation between the actual amount of antibody produced and the amount of colostrum and milk secreted from an individual teat. Svendsen (1972) estimated that 16% of 2-day old pigs are hypo-gammaglobulinemic, with the serum gammaglobulin levels in a population of 2-day old pigs following a normal distribution curve. Perry and Watson (1967a) summarized the factors influencing variation among litters as being; concentration of antibody in the dose; time elapsed between birth and dosing; sire; amount or composition of colostrum consumed.

The passively acquired antibodies decrease rapidly even within the first week of life (Harrold and Johnson, 1976) and have a half-life of approximately 9 days (Miller et al., 1961a). Miller et al. (1962a) reported the decline of colostrally-absorbed serum antibodies and immunoglobulins to occur logarithmically, with half-lives of 4.7 and 7.5 days, respectively. Several researchers report that the passively acquired antibodies decline markedly after 3 weeks of age (Brown et al., 1961; Hoerlein, 1957; Kelley and Nayak, 1965) but persist at a low level until the pigs are about 6-weeks of age (Brown et al., 1961; Harrold and Johnson, 1976). Wilson and Svendsen (1972) reported that at 2-days of age the pig's gammaglobulin levels are twice those of an adult, while at 3-weeks of age it was only 25% of the adult level, and as early as 7-days of age they were able to measure only very low levels of gammaglobulins.

Active Immunologic Development

Wilson (1974) reviewed and summarized some of the literature relating to the immunologic development of the neonatal pig. Although it was originally theorized that pre-existing antibody is necessary for antibody formation (Segre and Kaeberle, 1962a,b, 1964), more recent research finds no evidence to support this theory (Kim et al., 1966b,c). Harrold and Johnson (1976) reported that actively-produced antibodies are of greater protection for the pig than passively-acquired antibodies. Early research indicated that there was no active antibody production in pigs less than 3-weeks of age (Hoerlein, 1957; Jones et al., 1977; Miller et al., 1962a) while at 3-5 weeks of age they are in a period of increasing response to antigens (Brown et al., 1961; Harmon et al., 1973; Kim et al., 1966a; Lecce et al., 1962; Miller et al., 1962b; Wilson and Svendsen, 1972). Wilson and Svendsen (1972) stated that a lack of antibodies results in earlier activation of the antibody-producing system; apparently the immune response is delayed in the pig if its serum already contains passively-acquired antibodies to a homologous antigen (Hoerlein, 1957; Segre and Kaeberle, 1962b; Sterzl et al., 1966; Uhr and Baumann, 1961; Wilson and Svendsen, 1972).

Miller et al. (1962a) reported that gammaglobulin may be produced in pigs under 3-weeks of age, before active antibody production, although it is also reported that there is active antibody production in pigs 3-weeks of age, but the response was 20-times greater in pigs 6 weeks old. Recent research has indicated active antibody or immunoglobulin production in pigs as young as 15 days of age (Georgieva and Gerov, 1975), 12 days of age (Sharpe, 1965) and 10 days of age (Wilson, 1974; Binns, 1969; Hayes and Kornegay, 1978). Yabiki et al. (1974) reported that in colostrum-deprived pigs the IgG appears around 12 days, IgM about 9 days and IgA around the 16th. day. Other research has revealed that not only is the newborn, pre-colostral pig capable of synthesizing antibodies against certain antigens (Hajek and Mandel, 1971; Kim et al., 1966a,d; Binns, 1969; Long et al., 1964; Prodesova et al., 1968; Rejnek et al., 1974; Segre and Kaeberle, 1962b; Sokol, 1968) but even the swine fetus as early as the 80th. day of gestation has been shown to produce antibodies (Binns, 1969; Bogdan et al., 1968; Sokol et al., 1968).

The antibody response is greater in response to a single antigen than multible antigens, indicating antigenic competition (Kim et al., 1966a), and the response can be measured within 48-72 hours (Kim et al., 1966a,c, 1967; Hajek and Mandel, 1971) after the pig has been exposed to the antigen, and the immune response is primarily in the IgG portion (Porter and Kenworthy, 1970). The antibody response may be greater if antibiotics are included in the diet (Brown et al., 1961; Harmon et al., 1973) and at high dietary protein and lysine levels (McGillivray et al., 1964). Barta et al. (1970) reported that the microflora of the intestinal tract are one of the stimuli for a higher level of complement activity in the serum. Miniats and Valli (1972) reccomend colostrum-deprived pigs be gradually exposed to a controlled, harmless microbial flora prior to being placed with other animals.

Miller et al. (1957) reported that at 3-4 weeks of age, sow-reared pigs had superior antibody production to pigs weaned at 4-days of age and raised on a synthetic milk diet or commercial sow milk replacer, although the artificially reared pigs did exhibit an excellent antigen-antibody response. Haye and Kornegay (1978) compared the serum immunoglobulin levels between sow-reared and pigs weaned at 12 hours of age and reared artificially. Their data also indicated artificial rearing results in a slightly reduced antibody response and lower serum IgM levels, although the IgG and IgA levels were not different. Haye and Kornegay (1977) reported that antibody production in artificially reared pigs occurred at the same age as sow-reared pigs, but the magnitude of the response is less. Brown et al. (1961) reported that at 6-weeks of age there was no difference in the antibody titer between pigs weaned at 3-weeks of age and those still nursing their dam.

Disease Immunity During Artificial Rearing

Many of the difficulties when artificially rearing pigs may be related to the lack of antibodies in the serum and/or intestinal tract. McCallum and Owen (1976) reported that only 0-3% of their pigs survived if not fed colostrum or any other source of gammaglobulins. Colostrum-deprived pigs must be reared in strict isolation or administered a gammaglobulin source for most successful results (Mount and Ingram, 1971; Lecce, 1971; Lecce et al., 1961a; Bustad and Cunha, 1947; Bustad, Ham and Cunha, 1948; Pond et al., 1961; Scoot, Owen and Agar, 1972).

A happy medium must be found between the time required for the pigs to acquire passive immunity and removing the pigs before the high rate of mortality can occur. McCance and Widdowson (1957) reported that within 24 hours the pig plasma volume increased 30%, concentration of globulins increased about 300%, and the weight of plasma proteins increased by more than 200%. Coalson and Lecce (1971) reported that marked changes occurred in serum proteins within one hour and maximum serum protein changes occurred within 6 hours. Coalson and Lecce (1973a) also suggest that as little as one hour of equal nursing opportunity for all pigs is adequate, or if the pigs are gavaged with 40-60 ml of sow colostrum, the volume normally consumed by suckling pigs. Bengtsson (1971) reported that the pig required more than 150 ml of sow colostrum per kg bodyweight the first 20 hours post-partum for normal development of the serum nitrogen profile.

Many companies manufacture sow milk substitutes but do not claim that they are a substitute for colostrum. Since useful antibodies are related to what pathogens the sow has been exposed to, and there are many potential pathogens, the most economical means of supplying antibodies to the pig is through the sow's mammary secretions. Letting the pigs nurse the colostrum would be of little economic or physiological cost to the sow since colostrum is already present and suckling may help the tone return to the uterus (Lecce, 1971), plus colostrum and milk antibodies have value in regulating gut damage by microbes (Kohler and Bohl, 1966b; Rejnek et al., 1968). Lecce (1975) suggested that to protect the pig while its gut is immature, the herdsman, through dietary and management regimens, should limit contact with or the production of toxic macromolecules in the pig's gut, and provide a means by which the intestinal epithelium is continuously bathed with immunoblobulins.

Even after the gut is 'closed' it can be important for the pig that antibody continue to be in its diet. Numerous researchers report the benefits of immunoglobulins bathing the intestinal epithelium and providing a local protective effect (Coalson and Lecce, 1973a; Lecce, 1975; Rejnek et al., 1968; Wilson and Svendsen, 1971; Wilson, 1972,1974; Owen et al., 1961). Even colostrum-fed pigs when moved to a different nonsterile environment may exhibit illness which can be attributed to a lack of specific antibodies against pathogens to which the pig has not acquired protection against.

Circulating antibodies, derived from colostrum or injected antiserum, have little or no effect on enteric diseases, such as TGE and colibacillosis, since they are apparently unable to reach the site of infection (the intestinal mucosa) in sufficient quantities to prevent infection, but are effective in preventing septicemia (Haelterman, 1965; Hooper and Haelterman, 1966; Kohler, 1967);

Svendsen (1972) reported he found no relationship between the serum gammaglobulin level and the development of enteric colibacillosis, and pigs under 2 days of age are vulnerable to viral diarrhea even though they have a high level of circulating immunoglobulin (Lecce, 1973b; Lecce and Mock, 1973). Parenterally administered porcine immunoglobulin increase survival rates but the pigs do not gain well and suffer diarrhea (Lecce, 1972c; Lecce and Matrone, 1960; Owen _et al_., 1961), thus they do not provide effective passive immunity for colostrum-deprived pigs (Owen and Bell, 1964; Owen _et al_., 1961). Wilson and Svendsen (1972) found evidence that direct bactericidal activity is not regularly present in the pig's sera, thus the pig may be poorly equipped to effectively prevent colibacillosis.

Orally administered antibodies or immunoglobulins, via sow or bovine milk or colostrum, or antiserum, protects the pig from enteric diseases due to inactivation of the pathogen within the lumen of the alimentary tract by the antibodies (Haelterman, 1956; Hooper and Haelterman, 1966; Kohler, 1967; Lecce, 1973b; Lecce, Coalson and Mock, 1972; Lecce and Mock, 1973; Bruegger and Conrad, 1972; Kohler and Bohl, 1966b; McCallum and Owen, 1976; Svendsen and Wilson, 1971; Tlaskalova _et al_., 1970; Wilson, 1974; Elliot _et al_., 1975). Antibody, and IgA, which tend to remain in the gut and resist absorption, may be important in overcoming susceptibility to invasive Ecoli and may act directly on the bacteria (O'Donovan and Ensley, 1976; Sharpe, 1965). Ideally the antibody or gammaglobulin should be administered continuously throughout the milk replacer-feeding period (Kohler, 1967; Kohler and Bohl, 1966b; O'Donovan and Ensley, 1976; Scoot _et al_., 1972; Svendsen, 1972). Earle (1935) also suggested that milk substitutes and supplements should include substances from which the pig can derive passive immunity. Segre and Kaeberle (1962a) listed, in order of decreasing efficiency, methods by which colostrum-deprived pig's immunological deficiency at birth can be overcome as being: suckling colostrum; diluted hyperimmune serum of swine or horse origin; immune swine serum; normal serum from older colostrum-deprived pigs.

Elliot et al. (1975) reported best survival rates when pigs were fed 10 gm of gammaglobulin per kg bodyweight the first day, followed by 2 gm/kg/day for the next 9 days. Wilson (1972) calculated that pigs nursing the sow ingest approximately 3 grams of immunoglobulin per day and that amount in the diets of artificially reared pigs has been found to be sufficient for protection (Kohler, 1967). McCallum and Owen (1976) reported that the survival rate increased when colostrum-deprived pigs were fed immunoglobulins from abattoir blood and improved even further if antibiotics were added to the diets. Colostrum or serum from vaccinated sows gives significantly longer survival rates in pigs exposed to the same antigen than if the pigs are fed colostrum or serum from non-vaccinated sows (Svendsen and Wilson, 1971; Wilson, 1974).

Scoot et al. (1972) reported that a crude immunoglobulin preparation from abattoir blood serum could provide passive immunity when added to the milk replacer diet, with survival rates similar to pigs nursing sows. Some diarrhea occurred when the immunoglobulins were removed from the diet but the pigs recovered spontaneously. They also reported that unfractionated blood serum was impractical because the large quantity required to provide 5-15 gm of immunoglobulin per day resulted in an unpalatable diet. Elliot et al. (1975) also found serum-derived porcine immunoglobulin preparations added to milk replacer diets greatly improved survival rates of colostrum-deprived pigs.

Yabiki et al. (1974) reccommended that in order to confer passive immunity to newborn pigs, gammaglobulins derived from pooled porcine serum should be subcutaneously injected into colostrum-deprived pigs and all pigs farrowed should be fed a mixture of artificial milk and dry serum or serum within 24 hours after birth. Lecce and Matrone (1961) reported that cow's colostrum fed to pigs which had not suckled resulted in superior weight gain and viability to pigs not fed a source of immunoglobulin. Edwards (1965) reports that the 2 pints of colostrum removed from the cow does not have any detrimental effect on the calf.

DIGESTION

Sow's Colostrum and Milk

There have been many determinations of the average yeild and composition of sow milk. Reviews by Bowland (1966) and Heidebrecht et al. (1951) describe the changes as lactation progresses. Variations are found in the literature concerning actual percentages of the various constituents of sow's milk, such as fat (Elliott et al., 1971; Bowland et al., 1949b; Perrin, 1954), and protein (Perrin, 1955; Elliott et al., 1971; Bowland et al., 1949b).

Sow's milk is similar in composition to ewe's milk except sow's milk is higher in ascorbic acid and lower in riboflavin content; sow milk has twice the fat content as cow milk and is also higher in total solids, solids-not-fat, protein, ash, calcium and phosphorus, although the lactose content is similar (Braude et al., 1947).

Sow's colostrum and milk composition varies widely from sow to sow (Braude et al., 1947; Elliott et al., 1971). In addition, there is not only a daily or weekly variation in composition of an individual sow's milk (Bowland et al., 1949b; Perrin, 1954), glands on the same sow may vary (Pond et al.,1962). Glands on an individual sow may also differ in yeild (Hartman et al.,1962) and even a single gland can vary in yeild at each hourly nursing within a 24-hour period (Barber et al., 1955). Thus there can be considerable variation in quantity and quality of milk obtained by each piglet. Milk yeild is influenced by many factors, including diet and inherent ability of the sow. Level of sow feeding during lactation (Lodge, 1969) and litter size (Allen and Lasley, 1960) also influence yeild. The increase in milk production by a sow with a large litter is not linear (Buchanan and Donald, 1937); therefore, although the total milk production increases, the amount per pig may decrease. Large pigs consistently obtain more milk than small (Barber et al., 1955; Donald, 1937a), perhaps because they are more vigorous and empty glands more completely and stimulate greater milk production (Hartman et al., 1962). The situation is rare where there is more milk available than the pigs want, and they are generally never satisfied (Barber et al., 1955).

Pigs efficiently convert milk into liveweight gain (Barber et al., 1955) although pigs receiving milk in excess of requirements may be less efficient in conversion (Barber et al., 1955; Braude et al., 1947; Menge and Frobish, 1976a).

The composition of colostrum is markedly different than that of milk produced later in the lactation period. The colostrum composition is influenced by sow diet (Elliott et al., 1971) especially during gestation (Lodge, 1969). The colostrum, as compared to milk, is higher in protein (Brent et al., 1973; Perrin, 1955; Colenbrander et al., 1967; Hughes and Hart, 1935; Miller et al., 1963b; Elliott et al., 1971; Bowland et al., 1948; Pond et al., 1962; Sheffey et al., 1952c) and solids (Brent et al., 1973; Colenbrander et al., 1967; Hughes and Hart, 1935; Bowland et al., 1948; Braude et al., 1947), but lower in lactose (Colenbrander et al., 1967; Perrin, 1955; Miller et al., 1963b) and ash (Perrin, 1955; Miller et al., 1963b; Pond et al., 1962). Reports on fat content are conflicting; some report that colostrum is lower in fat as compared to milk (Perrin, 1955; Hughes and Hart, 1935; Friend, 1974) while others report the reverse (Sheffy et al., 1952b; Pond et al., 1962; Braude et al., 1947; Colenbrander et al., 1967). The change from colostrum to milk takes somewhere between 4 and 7 days, and as lactation progresses the composition of milk also changes (Holme, 1969). In general the dry matter of milk is approximately 20%, lactose 5%, protein 6%; it is 35-40% fat on a dry matter basis. The vitamin content is variable but generally adequate for the piglet's needs. Milk is a highly digestible feed and the major nutrients have digestibility coefficients of the order of 97-98%, and normally contains adequate amounts of all nutrients except iron (Holme, 1969).

The protein portion of milk contains a number of different protein types, of which casein is the major component. The important factors in digestion of milk protein seems to be the ability of the diet to clot, retention of digesta in the stomach and high proteolytic enzyme activity in the small intestine resulting in rapid hydrolysis of dietary nitrogen (Braude et al., 1970a). Pepsin, rennin and HCl in the stomach cause casein to clot (Brent et al., 1975) within 15-30 minutes (Braude et al., 1970b) while the soluble whey fraction, containing water, dissolved lactose, minerals in solution and some protein and fat, rapidly passes into the small intestine where it is digested. Pepsin and lipase in the stomach act on the clot to crumble it and small pieces pass on into the small intestine; most of the clotted digesta leaves the stomach within 2 hours after the meal (Braude et al., 1970b). Although the stomach pH decreases to a level near optimum for pepsin activity, relatively little proteolysis occurs in the stomach; the small intestine is the site of most protein digestion.

Digestion of Nutrients

Glucose: Glucose does not require any digestion and is quickly absorbed although its absorption requires a healthy intestine and damage caused by severe scouring may slow absorption. In artificial diets glucose is a satisfactory source of carbohydrate in terms of piglet gain and survival (Aherne et al., 1969a; Becker et al., 1954b).

Fructose: Fructose is the principal sugar of fetal blood (Aherne et al., 1969b) and is at a high level at birth (Aherne et al., 1969b; Pettigrew et al., 1971). The blood fructose level rapidly decreases after birth (Aherne et al., 1969b; Bille et al., 1975; Curtis et al., 1966; Frobish, 1969a; Steele et al., 1970) but this is due mostly to excretion since there is an extremely slow rate of fructose metabolism by the newborn pig (Aherne et al., 1969b). In artificial diets with fructose as the carbohydrate source, Becker et al. (1954b) reported no weight gains and severe diarrhea in the piglets; Aherne et al. (1969a) also reported that pigs between 2 and 4 days of age lost weight, had poor feed efficiency and high mortality, and and the fructose was poorly utilized until the pigs were at least 6 days of age.

Lactose: Lactose is the milk carbohydrate. Some is fermented in the stomach by lactobacilli; the lactic acid which is produced may be absorbed and utilized by the piglet, and the stomach acidity also aids protein digestion and may hinder any pathogenic organisms the pig may ingest (Brent et al., 1975). The lactase level is high the first 2-3 days (Campbell et al., 1971) and is maintained at a constant level to 5 weeks of age (Walker, 1959; Hartman et al., 1961; Ekstrom et al., 1975). Lactose is a staisfactory source of carbohydrate the first week of the pig's life (Aherne et al., 1969a); Becker et al. (1954a) reported no diarrhea in pigs 1-2 days of age fed lactose-based diets and Mateo et al. (1977, 1978) reported that the digestible energy level of lactose and glucose are equally well utilized by the baby pig.

Sucrose: Sucrose must be hydrolyzed into glucose and fructose before it can be absorbed and utilized. Sucrase levels increase with age (Walker, 1959; Hartman et al., 1961) and sucrose is poorly utilized until the pig is at least 6-7 days of age (Aherne et al., 1969a; Mateo et al., 1977, 1978; Becker et al., 1954a). Using sucrose in the diet before the pig is at least 1 week of age results in the failure of the pig to grow and survive; the pig either does not gain or loses weight, has a higher incidence of mortality and severe scours (Aherne et al., 1969a; Becker et al., 1954a,b; McRoberts and Hogan, 1944; Edwards, 1965) although the pig's appetite remains excellent (Becker et al., 1954b). Pigs which survive until they develop higher sucrase levels then make rapid and efficient gains (Becker et al., 1954a; Edwards, 1965).

Maltose: The pig can utilize small amounts of maltose at birth (Cunningham and Brisson, 1957a,c) due to low levels of maltase (Walker, 1959). The maltase level increases with age (Shields et al., 1977b; Hartman et al., 1961; Walker,

1959) and the rate of digestion of maltose-based diets may be borderline for optimum feed consumption and growth in the very young pig. After 1 week of age, however, pig performance is the same if fed glucose or maltose, and although less digestible than glucose, maltose is 97.4% digestible at 2-5 days of age (Cunningham and Brisson, 1957c).

Starch: It would be economically adventageous if starch could be substituted for lactose in sow milk replacers for baby pigs, but this in not possible since the starch is not well utilized. The digestion of starch requires alpha-amylase and maltase. As stated, maltase activity increases with age; amylase activity is also low at birth and increases with age (Hudman et al., 1957; Shields et al., 1977b; Walker, 1959; Hartman et al., 1961; Scherer, Hays and Cromwell, 1973). Walker (1959) suggested that the limiting factor to greater breakdown of starch by the young pig may be its inability to effectively utilize the products of starch hydrolysis. Corn starch is poorly utilized until at least 35 days of age (Mateo et al., 1978; Smith and Lucas, 1957a) and is inferior to lactose as the carbohydrate source for baby pigs (Wilbur et al., 1960). Cunningham and Brisson (1957a) reported that when starch was included in the baby pig diet as the carbohydrate source, the pigs rapidly developed rough coats, appeared unthrifty, grew slowly and lost weight, although their condition began improving after 2 weeks of age. Although Cunningham (1959) proposed that the main factor restricting digestion of raw starch by piglets is the initial rupture of the starch preparation and reported that a soluble starch preparation was digested more rapidly than raw starch, Cunningham and Brisson (1957a) reported that a cooked starch diet was inferior to raw starch as the carbohydrate source in the baby pig diet. When Cunningham and Brisson (1957c) fed less digestible carbohydrates, the pigs were more gaunt and excreted softer feces although feed intake and growth rate were not significantly affected. Shields et al. (1977a) reported there were significant dietary treatment effects on total amylase activity, although protease and maltase activities are unaffected and Cunningham (1959) concluded that the rate of digestion and absorption of glucose, maltose and soluble starch are high enough to meet most of the piglet's energy requirements although the consumption of large quantities of these can result in diarrhea.

Fat: Sow milk is rich in fat and the pig easily digests it. Hartman et al., (1961) reported that pancreatic tributyrinase level is high at birth and gradually increases with age; Scherer, Hays and Cromwell (1973) reported an increase in lipase activity after birth and a quadradtic increase in apparent digestibility of fat with age. Many other researchers also report significant increase in fat digestibility with age (Frobish et al., 1966, 1969, 1970, 1971; Eusebio et al., 1965; Leibbrandt et al., 1975a; Lloyd and Crampton, 1958). Sherry, Schmidt and Veum (1978a) reported that the digestibility of fat varies with the source and level of dietary fat.

Apparently in young pigs there is an inverse relationship between apparent digestibility and molecular weight of the fat or oil (Lloyd, Crampton and MacKay, 1957; Sherry et al., 1978b; Frobish et al., 1970) and as the pig becomes older and digestion improves, the difference in digestibility between types of fat diminishes. Sow milk fat is present as small globules and is easily digested, but fat used in sow milk replacers does not have such a high availablility and emulsification does not enhance the utilization of fats (Sheffy et al., 1951; Frobish et al., 1969). Eusebio et al. (1965) concluded that the molecular weight is not theonly factor determining the efficiency of utilization of fats by the baby pig; for example, protein source may influence the efficiency of fat digestion (Frobish et al., 1970). The baby pig can partially compensate for substitution of carbohydrate calories with fat calories (Wolfe et al., 1975) and by 5-6 weeks of age can utilize fat calories as effectively as carbohydrate calories (Allee, Baker and Leveille, 1971; Allee and Hines, 1972; Cline et al., 1977).

Results of experimental feeding of fat to baby pigs have been variable, mainly due to differences in physical forms of the fats or the level of feeding used. Since as the level of fat is increased, in either liquid or dry diets, there is a decrease in feed intake (Frobish et al., 1969), nutrient intake decreases. Thus there may be a decrease in growth rate and feed efficiency as the fat level of the diet is increased (Frobish et al., 1967; Frobish and Johnson, 1956; Leibbrandt et al., 1957a) unless there is compensation for decreased nutrient intake. A high-fat diet may also soften the feces and the laxative effect can sweep undigested carbohydrate to the hind gut where they are fermented and lead to diarrhea (Brent et al., 1975).

Protein: Proteinase activity of the baby pig is low at birth and the first 2 weeks but then rapidly increases with age (Hartman et al., 1961; Shields et al., 1977b; Lloyd and Crampton, 1958; Eusebio et al., 1965). There is negligable pepsin activity at birth but the activity rapidly increases although the actual quantity is low until approximately 3 weeks of age (Lewis et al., 1957). Lewis et al. (1957) report that at birth the pig is capable of producing a relatively large amount of trypsin; however, there was considerable variation from litter to litter and even pig to pig and they propose some pigs may have an inadequate level to hydrolyze the less-digestible vegetable proteins.

The baby pig efficiently digests milk proteins and gradually develops the ability to digest a wider range of proteins. Ilsson (1959) reported that the efficiency of the digestion improves considerably with age in the case of soybean protein and improves to a lesser degree with milk protein. Pond et al. (1971a) suggest that while pancreatic exocrine function is not an important factor in affecting overall performance of piglets fed diets of different protein composition, the enzymes of the stomach or intestines are sensitive to dietary protein, and this is related to inferior performance of pigs fed isolated-soybean protein.

Estimated protein requirements of baby pigs vary widely, primarily due to considerable differences in test diets in solids content, digestibility, energy value, amino acid content, ingredients, relative proportions of ingredients, rate of food passage, frequency of feeding, and whether fed as a liquid or dry meal. The dietary level or quality of protein not only affects the pig's rate of gain (Schneider and Sarett, 1969; Filer et al., 1966) and caloric efficiency (Filer et al., 1966), but also the amount of carcass fat (Filer et al., 1966; Khafaren and Zimmerman, 1971; Zimmerman and Khafaren, 1973), carcass protein (Schneider and Sarett, 1969; Khajaren and Zimmerman, 1971), amount of liver glycogen (Schneider and Sarett, 1969) and hemoglobin and plasma protein levels (Schneider and Sarett, 1969). Feed intake is depressed by both sub-optimum (Crampton and Ness, 1954; Harmon et al., 1973; Hutchinson et al., 1957a) and super-optimum protein levels in the diet (Hendricks et al., 1970). Sheffey et al. (1952c) reported that with baby rats the source and level of dietary protein influences the magnitude of endogenous protein secretions such as the digestive enzymes trypsin, chymotrypsin and amylase. Kellogg et al. (1964) reported that the level or source of dietary protein affected the fecal flora of pigs.

The pig has a very high protein requirement and the level of protein and/or amino acids needed for maximum feed utilization and growth decreases as bodyweight and age increase (Reger et al., 1953; Hutchinson et al., 1957b; Dudley et al., 1962; Smith and Lucas, 1957c; Lloyd and Crampton, 1960; Reber et al., 1953; Menge and Frobish, 1976b). Runt pigs may require more protein than larger littermates since, in general, they tend to excrete excessive amino acids (Mason et al., 1960).

In addition to nutrient quality, other factors must be considered when selecting protein sources for artificially reared pigs. Factors, not explainable in terms of classical nutrient content, indicate the pig requires complete proteins in its diet since diets containing whole milk protein are superior to synthetic milk diets of equivalent amino acid value (Dudley et al., 1962; Barrick et al., 1954; Lecce et al., 1961a). Lecce (1973a) data also implies the pig's protein needs involve more than just a supply of amino acids and the pig needs specific kinds of protein. Dudley et al. (1962) and Mitchell et al. (1968) report improved performance if casein is added to an amino acid diet. A diet containing whole milk protein may be superior to an amino acid diet due to the ability of the complete protein to clot in the stomach so there is an increased efficiency of utilization through decreased rate of passage.

Because of wide differences between proteins in their value to young pigs, protein requirement can not be expressed with any accuracy without reference to the source since the quality of the protein has considerable influence upon the performance of the baby pig. For maximum rate of gain and feed efficiency, rations must contain relatively large quantities of costly protein sources of high biological value.

The differences between digestibilities of protein sources disappears with age (Maner et al., 1961; Combs et al., 1963) and the pig is unable to completely digest vegetable protein until approximately 4-5 weeks of age (Combs et al., 1963; Hays et al., 1959). The digestibilities of milk protein and fish meal are high and improve little with age, while the digestibilities of protein from cereals and soybean meal increase between 2 and 8 weeks of age.

Milk protein appears to be the best single protein source in terms of gain and feed efficiency, and is digested efficiently at many different levels of feeding (Braude et al., 1970a,b). Milk protein is superior to egg white (Lecce and Matrone, 1961; Pettigrew and Harmon, 1975, 1977), soybean protein (Lecce and Matrone, 1961; Pekas et al., 1964; Maner et al., 19591 Ducharme and Armstrong, 1977; Libal and Wahlstrom, 1976; Lewis et al., 1955) and fish protein (Lecce and Matrone, 1961). An unsatisfactory protein source in the diet results in a decreased rate of gain and feed efficiency, and an increase in incidence and severity of diarrhea and perhaps an increase in the mortality rate. Sherry, Schmidt and Veum (1978a) reported that if the pigs are fed a diet with less than 25% of the protein in the diet as milk protein, their subsequent performance is depressed. Zamora et al. (1975) reported that soybean protein could be a major source of protein for artificially-reared pigs; however the diets fed also contained 46% dried skim milk and 10% whey.

Although Weybrew et al. (1949) reported no difference in the efficiency with which solids from dried skim milk, whole milk powder or evaporated milk are utilized for growth, not all milk proteins are suitable as the sole source of protein for the pig. The mixture of proteins in milk has a higher biological value than casein (Hendricks et al., 1970) and diets with fish protein sources may be equal to casein-based diets (Pettigrew et al., 1972; Pond et al., 1971). Yet casein as the sole protein source is superior to soybean protein even if the soybean protein is supplemented with methionine (Maner et al., 1954; Pond et al., 1971). Lecce and Coalson (1976) reported that if dietary protein is exclusively from isolated calcium caseinate the growth rate of the pigs does not equal that of sow-reared pigs, but the growth rates are equal if 50% of the caseinate is replaced with nonfat milk solids. Pettigrew et al. (1977) reported that peptonized milk (a tryptic digest of skim milk) was an unacceptible as a protein source for artificially reared pigs, and when substituted for dried skim milk in the diet the pigs suffered a decreased rate and efficiency of gain and extreme diarrhea.

In most reports, as the dietary protein level is increased in baby pig diets there is a corresponding increase in the efficiency with which the food is utilized and faster rate of gain (Khajaren andZimmerman, 1971; Peo et al., 1957; Menge and Frobish, 1976b; Jensen et al., 1957; Reber et al., 1953); Iowa State University studies (Anon., 1973a) indicated there is also an improved survival rate with higher protein diets. Mitchell et al. (1968b) indicated increasingly efficient utilization of amino acids as protein levels are increased until dietary needs are met. Reber et al. (1953) reported that pigs receiving less than 25% crude protein in the diet required more than 1 kg of feed for each kg of gain, while pigs receiving more than 25% dietary protein required less than 1 kg feed per kg gain.

In research where diets were based on high quality protein sources, generally the best results were obtained with the highest protein level fed in each experiment. Sewell et al. (1953b) reported that diets, based on isolated-soybean protein and casein, with only 16% or 20% crude protein resulted in the retarded growth of baby pigs. Most estimates of protein required by pigs range between 28 and 30% (Jurgens, 1974; Smith and Lucas, 1957a; Peo et al., 1957; Manners and McCrea, 1963a; Lecce and Coalson, 1976; Anon., 1973a) although Reber et al. (1953) reported 41% was best, and Sewell et al. (1953b) reported 32% to be optimum. Pettigrew et al. (1972) reported that a diet based on fish flour required 33.5% crude protein. Klay (1964a,b) reported that there is a decreased efficiency in protein and lysine utilization as the level of dietary protein is increased and the lysine requirement increases due to this decreased efficiency of absorption.

Amino acid supplementation may improve pig gain and feed efficiency of lower protein diets (Cline et al., 1974) but there is only a small response to changes of dietary level of a poor quality protein or an imbalenced assortment of essential amino acids (Dudley et al., 1962). The results reported by Braude et al. (1970a) indicate that it may be advantageous to feed large amounts of protein early in the pig's life when the dietary nitrogen is utilized with the most efficiency.

The protein required for early weaning diets based on high quality milk protein sources is generally less than that reported for the younger and lighter artificially-reared pigs' diet. There are also more variations in protein sources as substitutes of vegetable protein sources are used. Rodriguez and Young (1978) report that pigs weaned at 7 days of age performed best on diets of 28% protein. For pigs weaned at 10 to 14 days of age, LLoyd and Crampton (1960) and Blair (1961) report that 23-24% crude protein in the diet is adequate, and 20% crude protein is inadequate (Lloyd and Crampton, 1960). In contrast, Crampton and Ness (1954) reported that 26% crude protein is below optimum and 30% is preferable, and Smith and Lucas (1957a) reported that 29% crude protein is adequate. Lucas, Calder and Smith (1959a) reported that with 29% there is a considerable range over which skim milk and fish meal can be interchanged, since the total protein content probably is sufficiently high to mask small differences in feed values between the 2. Hays et al. (1959) reported that for pigs weaned at 10 days of age, dried skim milk is still superior to soybean meal as a source of protein.

For pigs weaned at approximately 3 weeks of age, slightly lower protein level is needed and more soybean meal can be utilized. But some animal protein, especially milk, appears necessary for best results (Holme, 1969; Jones and Pond, 1964). Meade et al. (1964) and Kornegay, Thomas and Kramer (1974) report 18% crude protein is adequate for rapid gain and feed efficiency on starter diets. Rutledge, Hanson and Meade (1961) report that pigs weaned at 3 weeks of age require at least 20% dietary protein of high quality to promote maximum nitrogen retention during the early stages of the subsequent growth period, and the amount of protein required to promote satisfactory nitrogen-retention. However Holme (1969) and Rust, Meade and Hanson (1972) reccomend 22% crude protein for pigs weaned at 3 weeks of age, and Lloyd et al. (1961) reported that the apparent digestibility of protein and carbohydrates were significantly higher with 30% than 22% crude protein diets, although they were equal in promoting gain and feed efficiency. Lloyd and Crampton (1958) also reported equal feed efficiency and digestibilities with 26% and 30% crude protein diets. Menge and Frobish (1976b) concluded that pigs weaned at 3 weeks of age can be fed diets of 20-24% crude protein with a calorie:protein ratio between 15 and 18. Milk products are still usually superior to vegetable protein sources at this age (Jones and Pond, 1964), although Jones, Coalson and Lecce (1977) reported that nonfat milk solids are equal to soy flour at 3 weeks of age when fed hourly as a liquid.

The protein content of creep feeds are a special case because they are usually not the sole diets, but merely a supplement to sow's milk. Jones (1969) concluded that the optimum level of protein in creep feeds is less than that of early-weaning diets and the protein quality is less critical. Holme (1969) reported that the limiting factor to piglet growth when fed creep feeds while still nursing the sow is feed consumption, rather than dietary protein or energy levels.

In several reports there was no improvement in feed efficiency or daily gain if the dietary protein level was increased beyond a certain level (Manners and McCrea, 1963a; Lecce and Coalson, 1976; Lloyd and Crampton, 1958; Rodriguez and Young, 1978; Wyllie et al., 1969; Smith and Lucas, 1957a; Blair, 1961). Reber et al. (1953) reported a tendency for the biological value to decrease as the protein level was increased. Smith and Lucas (1957a) reports that growth rate increases until the optimum protein level is reached, beyond which the rate and efficiency of growth may decrease. Baker et al. (1962) reported that in early-weaning diets supplemented with amino acids, excessive protein resulted in depressed gain and diarrhea, and hypertrophy of kidneys probably due to the extra work required to eliminate excess urea. Muramatsu et al. (1971) indicated that excess amino acids may depress protein synthesis.

Muramatsu et al. (1971) reported that the severe depression of growth caused by excess dietary amino acids is partially counteracted by an increase in dietary protein level, except when there is an excess of methionine; Harper et al. (1970) also noted that mentionine is the most toxic amino acid for the baby pig. The data from these 2 studies also indicated that an excess of essential amino acids caused more severe growth depression than an excess of non-essential amino acids. Muramatsu et al. (1971) theorized that in a high protein diet an excess of amino acids may be diluted with amino acids in the excess protein and the resultant whole amino acid balence may be corrected, or perhaps feeding a high protein diet may induce the amino acid-catabolizing enzyme thus the facilitating the metabolism of excess amino acids. Harper et al. (1970) concluded that the effects of excessive dietary amino acids depends on the type and degree of disproportion of amino acids, and on the nutritional and physiological state of the pig; a healthy animal receiving an adequate quantity of all essential nutrients tolerates a considerable dietary disproportion of amino acids without exhibiting adverse effects on growth and feed intake. They summarized 3 types of dietary disproportion, apart from amino acid deficiencies and excessive total protein intake, that result in adverse effects and classified them as: amino acid toxicities; antagonisms; imbalences. Symptoms may be alleviated by increasing the dietary protein content or improving the nutritional quality of the protein, and if the excess is not too great the animal adapts to the diet and its condition gradually improves.

To some extent a compromise can be made between the level of dietary protein and performance in order to reduce the total cost of feed per pig. Sewell et al. (1953b) reported fastest gains and most efficient feed utilization with a 32% crude protein, isolated-soybean protein and casein diet for pigs; however, 24% and 28% crude protein diets gave satisfactory results without resulting in retarded growth. Thus the producer may find it more economical to feed for slightly less than optimum performance by lowering the level of costly protein supplements in the diet. Wyllie et al. (1969) concluded that diets containing varying levels of protein, if the proteins are of equal and high quality, can be fed during the early growth period due to the marked compensatory carcass changes during the subsequent growth period. Meade et al. (1969) concluded that rapid gains are not necessary in the early growth period of early-weaned pigs to assure maximum gain and feed efficiency at heavier weights.

Digestive enzymes may be influenced by the pig's diet. Campbell et al. (1971) reported that although artificially-reared and sow-reared pigs had similar patterns of development of specific enzyme activity, the artificially-reared pigs' levels are lower than the sow-reared pigs'. Hartman et al. (1961) also reported that early-weaned pigs had lower concentrations of proteinase, amylase and pancreatic tributyrinase than sow-reared pigs. Frobish et al. (1970) reported that creep-fed pigs had higher levels of trypsin and chymotrypsin activities than pigs not allowed access to creep feeds. Mersmann and Stanton (1972) also reported increased digestive enzyme activities in creep-fed pigs. Dietary treatment may also affect digestive enzyme development of amylase (Shields et al., 1977a) and lipase (Scherer, Hays and Cromwell, 1973) but not protease or maltase (Shields et al., 1977a). Pekas, Thompson and Hays (1966) reported dietary effects on secretion rate and composition of pancreatic juice of pigs between 3 and 7 weeks of age, and an association between the volume of juice secreted and the quantity of diet consumed. In addition, they noted an association between the secretion rate and the person present.

ARTIFICIAL REARING

Introduction

Many producers are interested in a system which would allow them to save orphan pigs, surplus pigs from large litters or pigs from sows with lactation problems, as well as saving the 2 pigs farrowed alive but not weaned, thus lowering the high pre-weaning mortality level. They are also interested in weaning the pigs early so that the breeding cycle of the sows is shortened as well as attempting to break some disease and internal parasite cycles.

Maximum reproductive performance is of great economic importance; the high cost of producing weanling pigs is associated with the low number of pigs annually produced and low litter weight per sow, resulting in a high overhead per kilogram of pig produced. The number of pigs weaned per litter and the frequency with which the sow farrows has an important influence on production costs since the more pigs over which the cost of sow maintenance can be spread, the lower the cost per pig and the greater the return per sow.

For the commercial producer, there are greater losses sustained by the chronic loss of a few pigs in each litter than by whole litter losses. By reducing the pre-weaning mortality the producer can increase production level without increasing the number of sows farrowed. Bille et al. (1976) reported that saving pigs in the neonatal period does not increase the mortality rate in the remaining pre-weaning period. In addition to overt losses from the death of pigs, there is economic loss from suboptimal performance of weak, unthrifty piglets.

To increase the number of pigs produced per year, the size of litters may be increased but the national average litter size remains stable at about 7.2 pigs (Leman, 1976). The heritability of litter size in swine is low (Boylan et al., 1961) and attempts to markedly increase the litter size have not been very successful (Longenecker and Day, 1968; Bazer et al., 1969a,b,c; Pope et al., 1968) and under existing management conditiona, there is little advantage in farrowing very large litters since it is offset by increased pre-weaning mortality. Therefore it is presently most feasible to increase the level of production without increasing sow numbers by reducing preweaning mortality and reducing the farrowing interval.

Sows exhibit a nonfertile heat 1-3 days post-partum (Baker et al., 1953) and attempts to induce ovulation and fertility in lactating sows have been relatively unsuccessful (Peters et al., 1969b). Apparently the suckling stimulus prevents follicular development in post-partum sows (Peters et al., 1969b). Artificially rearing the pigs could theoretically reduce the lactation period to zero, thus shortening the interval to rebreeding. However there are reproductive problems in the sow when the pigs are weaned at birth or a few days post-partum: the sows have an increased interval from weaning to fertile estrus (Self and Grummer, 1958; Svajgr et al., 1974), increased incidence of abnormal estrus (Svajgr et al., 1971) and increased incidence of cystic follicles (Baker et al., 1953; Svajgr et al., 1971, 1974; Krug et al., 1975). When the sows are bred, there is a decrease in percent ova fertilized (Krug et al., 1975; Svajgr et al., 1974), decreased number of live embryos (Svajgr et al., 1971, 1974; Krug et al., 1975; Moody and Speer, 1970, 1971) and a reduced pregnancy rate (Moody and Speer, 1970; Svajgr et al., 1974). Apparently it takes 21-28 days for the sow's uterus to complete involution (Palmer et al., 1965) and the stimulus of suckling appears necessary for more rapid uterine involution (Peters et al., 1969); when the pigs are weaned early the uterus may not completely involute (Svajgr et al., 1971). Thus at the present time, weaning the entire litter at approximately 3 weeks of age is the earliest feasible time without decreasing the conception rate (Svajgr et al., 1971).

The production of SPF pigs has provided much insight of the piglet's nutritional and environmental requirements, but the elaborate equipment and methods required to produce SPF pigs are not practical under farm conditions (Berry et al., 1962). However, Bock and Bustad (1974) summarized many studies in which such a system can be of great benefit.

Most producers wean pigs when they are approximately 6 weeks of age although there is a definite trend towards weaning the pig earlier, at approximately 2-3 weeks of age. But the major portion of mortality occurs the first 7 days, and early weaning at even 10 days of age will not reduce the level of pre-weaning mortality very much. Currently artificial rearing is rarely done except as part of a disease eradication program, such as SPF production, or as research projects.

The earlier the pig is weaned, the more difficulties arise and greater death losses occur in a non-sterile environment (Lecce and Mock, 1973; Catron et al., 1949; Bustad et al., 1948; McRoberts and Hogan, 1944). Careful attantion must be paid to sanitation, nutrition, management, disease prevention and treatment, and all other conditions in conjunction with the pig's well-being. Researchers and producers who have artificially reared pigs all agree that a great deal of careful and intelligent management is required (Beattie, 1973; Montgomery and Johnson, 1972). Yet even under the most attentive management, failure may occur due to disease problems, some of which may arise from the pig's critical nutritional needs. More information is needed on how to meet the special needs of the baby pig in a challenging environment, allowing the pig to approximate or surpass weight gains of conventionally reared pigs, and not be expensive in terms of facilities and labor.

Even early weaning at 3 weeks of age can be difficult; there may be a higher death loss (Sewell and Maner, 1960) and pigs may be lighter at 8 weeks of age than those weaned at a later age (Meade et al., 1966a; Self and Grummer, 1958), although the feed cost per kilogram weight gain may not differ (Self and Grummer, 1958). Smith and Lucas (1957b) weaned pigs at 8, 14 and 20 lb. liveweight and concluded that the weight at weaning had no significant effect on age at 40#; weaning at heavier weights allowed them to feed less of an expensive starter diet, but the longer the pigs remained with the sow the more susceptible they were to flucuations in the sow's milk supply and the sow could not be rebred. Leibbrandt et al. (1975b) weaned pigs at 2,3 and 4 weeks of age and concluded that performance depended primarily on the feed intake if an adequate diet was fed; although feed intake and the rate of gain increased more rapidly after weaning as the weaning age increased, and older pigs were more adaptible to the post-weaning environment although the weight of pigs weaned at 2 and 3 weeks of age equalled those of pigs weaned at 4 weeks of age by 6 weeks of age. Kornegay et al. (1977) also noted that pigs weaned at 3 weeks of age had greater feed intake and rates of gain than pigs weaned at 2 weeks of age, but younger pigs overcame the initial post-weaning slump and had feed intakes and gains equivalent to or surpassing those of pigs weaned at 3 weeks of age.

The 2 main categories of problems associated with artificial rearing are: cost of labor and materials; materials and methods to acheive successful results. There have been mechanical problems in the machines used to feed the pigs and not all milk replacers match or surpass the quality of sow's milk. The milk replacers contain large amounts of expensive ingredients and it can take a large amount of expensive, skilled labor to raise the pigs. Thus for the producer to raise a maximum number of thrifty pigs per dollar cost to marketable or breeding age, the rearing system must be economical and consistently successful.

In some situations an alternative to artificial rearing would be to utilize foster sows (Anon., 1977). Bowland et al. (1949b) reported that 95% of the pigs survived if farrowings were attended, scouring was controlled, crushing protection was provided, heat was adequate for small pigs and individual supplemental bottle and/or pan feeding for weak pigs for a few days was practiced. Moody, Speer and Hays (1966a) reported increased gain and greatly reduced mortality if pigs with birth weights less than 1.14 kg were tube-fed with either 15 ml milk replacer once or twice daily, or pan-fed milk replacer twice daily, for 1 week.

There are several ways in which artificial rearing may be used under farm conditions. As mentioned previously, there is little sense in weaning the entire litter from a healthy, well-milking sow due to the reproductive difficulties encountered. But if the sow dies or is ill and suffers agalactia, obviously the entire litter can be removed and saved from starvation. The over-flow pigs from very large litters may be artificially reared, as well as the runts and injured pigs which cannot compete. An alternative would be to wean the biggest, healthiest pigs and leave the smaller pigs with the sow since with a good milk replacer the pigs will continue to develop well.

Artificial Rearing Methods

The baby pigs may be obtained via hysterectomy and reared in isolation or a germ-free state (Coadson, Maxwell and Hillier, 1971; England and Chapman, 1962; Cornelius et al., 1973) but this very expensive method has no practical use except in some types of research (Young et al., 1955; Bock and Bustad, 1974). In addition, pigs nursing the sow or artificially reared under disease-free, but not germ-free, conditions are significantly heavier at 3 weeks than germfree pigs (Whitehair et al., 1961). However, there are several methods that a swine producer with a high level of management skills can use to artificially rear pigs if he can provide a suitable environment and a nutritionally adequate diet. The method that best suits the producer is primarily based on how much skilled labor is available and how large an investment the producer wishes to make. He must decide on whether to group the pigs, feeding frequency, choose a liquid or dry diet, and whether to hand-feed or invest in a device which automatically dispenses feed.

One of the most basic methods was used by McRoberts and Hogan (1944) and Catron et al. (1949) who weaned the pigs between 2-3 days of age and grouped the pigs into floor pens with wood shavings; Catron utilized a poultry waterer to dispense the feed ad lib. Danielson (1972) weaned the pigs into groups of 6 and fed ad lib. from a gravity-fed, 3-nippled dispenser with a stirrer to keep the feed in a homogenious suspension. Foremost Foods Co. (Anon., 1973b) successfully raised pigs using no specialized equipment. They used 30" x 30" cages with 3 pigs per cage and fed ad lib. from plastic, gravity-fed dispensers; with this system one person could care for 288 pigs.

The pigs are often placed in individual metal cages with screened floors and are double- or triple-decked (Anon., 1973a; Danielson, 1968) with as many as 72 (Anon., 1973a; Johnston, 1974b) or 108 cages (Danielson, 1968). Kornegay (1977) reported that pigs in triple-decks consumed more diet and gained faster than pigs on slats when 2-3 weeks of age. Each cage may be equipped with 1, 2 or 3 feeding pans (Danielson, 1968; Johnston, 1974b; Coalson and Lecce, 1970). Hygiene is very important due to the piglet's limited defenses. The feed pans may be cleaned by dishwasher or washed by hand. Blaha and Kornegay (1975) handfed 3 times daily and by machine. More time was required to care for the handfed pigs and almost half the time could be eliminated if a dishwasher was used to clean the pans although this increased the investment.

Coalson and Lecce (1970) describe an elaborate "Auto-Sow" device. Pigs are caged individually and the volume of diet fed is programmed on the basis of each pig's weight. The trays move in and out of the cages and are cleaned automatically after each meal with hot chlorinated detergent sprayed under pressure and rinsed with cold water. A "Pig Mama" device similar to this, when managed properly, can save pigs and do it profitably (Johnston, 1974b).

Goodwin (1973) describes the Belgian system of artificially rearing pigs. The pigs are weaned between 4-10 days of age and weigh at least 2 kg. The wire cages are tripled-decked and sows are farrowed in batches of 3. One-third of the heaviest pigs are removed from the sows at 4 days of age and placed in the bottom cages; another third of the pigs are weaned at 6 days of age and the final group of pigs are weaned at 10 days of age. This method gives all pigs a good start on sow's milk and results in rearing 3 cages of evenly-sized pigs. The pigs are fed specially formulated milk replacement pellets and water twice daily.

Although successful results can be obtained when pigs are in small groups of 3-6 pigs (Anon., 1973b; Kornegay, Haye and Blaha, 1976; Montgomery and Johnson, 1972; McRoberts and Hogan, 1944; Pettigrew and Harmon, 1975; Danielson, 1972; Catron et al., 1949) the majority of pigs are caged individually (Anon., 1973a; Coalson and Lecce, 1970; Balconi and Lecce, 1966; Danielson, 1968, 1971; Johnston, 1974b; Lee et al., 1973; Lehrer et al., 1952; Miller et al., 1962b, 1964a, 1965; Schendel and Johnson, 1962; Schmidt et al., 1973; Sewell et al., 1953a; Sheffy et al., 1952a; Stothers et al., 1955; Wahlstrom et al., 1950; Zamora et al., 1975). When group feeding artificially reared calves (Anon., 1974), although it saved labor, weaker calves were shoved from feeders, there was less observation of individual calves, cross-infection was possible and it was not possible to adjust the intake of sick calves. Wilbur et al. (1960) reported that for pigs weaned at 2 weeks of age, individually-fed pigs gained faster than group-fed pigs, and Whittington and Ross (1974) reported that artificially-reared lambs had significantly faster daily gain when started individually rather than in groups of 6-12, and also had fewer vices which are detrimental to performance. To assure each pig a fair share of the diet, group-fed pigs should be provided with diet continuously or adequate space at the feed trough, with dividers, if fed on a schedule. Also there is some indication that calves reared individually, when grown they will produce more milk and be better mothers (Anon., 1974).

Some researchers have used nipples (Pettigrew and Harmon, 1975, 1977; Scoot et al., 1972; Danielson, 1972; Lehrer et al., 1952; Sewell et al., 1953a; Miller et al., 1964a; Kornegay, Haye and Blaha, 1976), but pan feeding is more common since the pig has no difficulty in learning to eat from a pan (Catron et al., 1949; Lee et al., 1973; Johnston, 1974b; Zamora et al., 1975; Coalson and Lecce, 1970; Schendel and Johnson, 1962; England and Chapman, 1962; Matrone, Hartman and Clawson, 1959; Danielson, 1968; Stothers et al., 1955; Balconi and Lecce, 1966; Miller et al., 1965; Anon., 1973a,b); Pettigrew and Harmon (1972) noted that the pigs in their experiments were sometimes slow to accept nipple-feeders. With dairy calves fed artificially (Anon., 1974), there was no difference in performance between pail and nipple feeding, but nipple-fed calves drank more slowly and nipple pails were harder to clean. Smith and Haywood (1969) reported that pigs fed with droppers often developed aspiration pneumonia from food in the lungs and the damage can persist 2 weeks even in the absence of micor-organisms, and there was no evidence of pulmonary damage if the pigs were allowed to feed naturally by drinking from a pan.

Environment

The environment must be carefully managed and the pig kept dry, warm and draft-free since it is very susceptible to cold, and chilling has been responsible for heavy losses among baby pigs. Curtis (1970) summarized many of the environmental-thermoregulatory interactions and pig survival. Stanton and Mueller (1976, 1977) reported that cold temperatures when artificially rearing pigs resulted in higher death losses and retarded growth the first 15 days of life, and some litters are more susceptible to chilling than others. The rate the pig develops hypoglycemia varies inversely with the environmental temperature (Morrill, 1952c).

Although thermogenesis, via sympathetically induced thermogenic response (Curtis and Rogler, 1970), is well-developed at birth (Mount, 1959; Mount and Rowell, 1960), the neonatal pig is functionally immature in temperature regulation (Holub, 1969) and thermostability improves with age (Newland et al., 1952; Foley et al., 1971; Curtis and Rogler, 1970; Curtis, Heidenreich and Harrington, 1967), especially the first 2 days (Curtis, Heidenreich and Harrington, 1967) although still not completely thermostable at that age (Newland et al., 1952). For the newborn pig the critical temperature is 34-35° C (Jensen, 1964; Mount, 1959, 1969) and the critical temperature decreases with age (Mount, 1960; Stephens and Mount, 1969), partly due to improved insulation as fat is deposited (Mount, 1963). At the same age, larger pigs have a lower critical temperature than smaller pigs (Newland et al., 1952; Mount and Stephens, 1970). Mount

(1960) reported the critical temperature to be 30-35°C for 2-4 kg pigs and 25-30°C for 4-8 kg pigs; Jensen (1964) reported the critical temperature to be higher than 35°C for pigs weighing less than 5.9 kg. There is a significant correlation between weight and ability to adapt to cold environments (Jensen, 1964; Newland et al., 1952) and Stanton and Mueller (1976) reported that pigs of low birth weight die especially early in cold environments. Runts, with a large surface area in proportion to bodyweight, lose body temperature more rapidly than larger littermates (Stanton and Carroll, 1974).

The pig increases thermal insulation and lessens body heat loss by vasoconstriction (Mount, 1963, 1964) and decreasing its surface by posture changes and some pilo-erection of its thin hair coat (Mount, 1963, 1964, 1967). Pigs in groups also conserve energy reserves and lessen heat loss by huddling (Jensen, 1964; Mount, 1960). Chilling the pigs when rearing them artificially may result in them ignoring their feed (Stanton and Mueller, 1976) and cold stress may have residual deleterious effects on subsequent thermo-regulatory capacity (Curtis, Heidenreich and Harrington, 1967; Jensen, 1964).

Although it has occassionally been reported that, in the apparent absence of disease, colostrum-free pigs were successfully reared (Catron et al., 1949; Perry and Lecce, 1968), pigs which have not received any colostrum are very difficult to rear artificially in a non-sterile environment (Lecce and Matrone, 1960; Lecce, Matrone and Morgan, 1961a; McRoberts and Hogan, 1944; Bustad, Ham and Cunha, 1948; Catron et al., 1949; Kornegay and Blaha, 1975; Owen and Bell, 1964; Owen et al., 1961; Pond et al., 1961) and 100% mortality can easily occur (Bustad and Cunha, 1947; Scoot, Owen and Agar, 1972). Even if the pigs have nursed, if the protective component, IgA, of sow's milk is not provided in the diet, then exposure to possible pathogens must be minimal so that the pig's limited defenses are not overwhelmed.

A compromise must be reached between the time required for the pig to nurse a sufficient amount of colostrum for passive protection to be established, yet wean pigs before the high death losses occur. Kornegay and Blaha (1975) weaned pigs at various times between 11 and 143 hours of age and reported that pigs weaned at 96 hours of age were easier to rear and the earlier pigs were weaned the higher the mortality, although the average daily gain was the same regardless of weaning age. Kornegay and Blaha (1975b) also compared pigs weaned at 12 vs. 96 hours of age and were successful at both weaning ages, with only a small difference, in favor of 96-hour weaning, in the incidence of scours and rate of gain. Stothers et al. (1955) weaned pigs between 72 and 96 hours of age, depending on the health and vigor of the pig. Some workers have waited until the pigs were 3-4 days old (Miller et al., 1955, 1962b; Veum et al., 1973; Schmidt et al., 1973; Smith and Lucas, 1957a; Mersmann, 1971) or 2-3 days of age (O'Donovan and Ensley, 1976; Jurgens, 1974). Weaning the pigs between 24-48 hours of age is the most common time (Lecce, 1971; Lehrer et al., 1949, 1952; Menge and Frobish, 1975, 1976a; Miller et al., 1965; McRoberts and Hogan, 1944; Schendel and Johnson, 1962; Sheffy et al., 1952a; Wahlstrom et al., 1950, 1952; Weybrew et al., 1947; Zamora et al., 1975). Danielson (1968, 1971) weaned the pigs when they were 6-12 hours, and Clark (1978) reported studies where pigs were allowed to nurse the sows until they had gained 40-50 gm rather than weaning strictly by age. Coalson and Lecce (1973) suggest, if all pigs are given equal opportunity to nurse, that one hour is sufficient for maximum serum protein changes to occur and the pigs may be weaned at that time. They also compared pigs weaned at 12 and 36 hours of age and reported that the pigs performed equally if they were farrowed in a relatively sanitary environment; however, if the pigs were farrowed in a contaminated environment, 12 hours of nursing was insufficient and pigs developed severe diarrhea and died.

Diets for Artificially Reared Pigs

Catron and Fact (1960) reviewed the factors influencing the feed intake of baby pigs and classified them as genetical, physiological, psychological, environmental and nutritional. Each of these has an important role when considering the diet of artificially reared pigs. Liquid diets, even though they may be messy and time-consuming to prepare, are usually fed to artificially reared pigs due to difficulties encountered when dry diets are fed. The feed must be nutritionally complete, palatable, of proper physical consistency and economical.

Pigs have adjusted to a dry meal diet before 7 days of age after receiving homogenized cow's milk for the first few days (Miller *et al.*, 1964a, 1965) but considerable labor is involved in placing dry feed in their mouths every few hours to train them to eat dry feed. Others have been able to adapt the pigs to solid diets at 7-8 days of age (Zamora *et al.*, 1975; Calder *et al.*, 1959; Hendricks *et al.*, 1969; Peo *et al.*, 1957); Mahan (1976) stated that, in general, the pigs can be weaned to dry diets at 12-14#. Menge and Frobish (1975, 1976a) weaned pigs at 2 days of age and fed cow's milk for another 24 hours. The pigs performed the same whether fed a semi-liquid diet (30:70 starter:milk) for 7, 14, 21 or 28 days followed by dry starter, and they concluded that it was practical to feed neonatal pigs an all-mash starter after 48 hours of colostrum and 24 hours of cow's milk. However, they noted that some pigs did not adapt to the change and refused to eat. Smith and Lucas (1957a) also noted that pigs weaned from the sow at 10 days of age to a dry meal varied widely in how rapidly they adjusted to the dry feed, and all pigs initially consumed small amounts. Meade, Dukelow and Wass (1964) also noted that pigs weaned at 3 weeks of age had not learned to eat, with resultant low total feed intake, and concluded that the pigs depended upon milk in the absence of established eating habits. Jansen *et al.* (1957) reported that with pigs weaned at 12-16 days of age and fed a dry feed, it took up to 5 days for some pigs to completely adjust.

Frobish *et al.* (1967, 1969) reported that a liquid diet fed *ad lib.* resulted in greater rates of gain and feed efficiency than *ad lib.* consumption of a dry diet. Catron (1963) noted that swine producers have observed that pigs eat liquid diets more readily and at a higher level of intake, and stay on feed better particularly under stressful conditions, than they do on dry feeds. He reported that until 5 weeks of age the pig eats more of a liquid sow milk replacer than dry meal, pellets or crumble type rations, and pigs weaned at 1 or 3 weeks of age consume more feed and grow faster on liquid diets than if started on dry rations. Crampton and Ness (1954) fed liquid and dry diets to pigs weaned at 10 days of age and noted that pigs may recognize liquid feed more quickly than a dry diet, and at first could not differentiate the dry diet from sawdust. They conclude that it is less a physiological matter when dry meal is fed than one of how quickly the pig learns to eat.

Pigs which are artificially reared may be introduced to dry starter diets when they are 6-8# (Johnston, 1974b; Fowler and Young, 1962), 7-8 days of age (Mitchell et al., 1968b; Danielson, 1972) or earlier (Stanton and Mueller, 1976). However, individual pigs may differ significantly in the amount of creep feed they consume (Barber et al., 1955). Catron et al. (1949) started to gradually decrease the amount of milk fed pigs 2 weeks before they were weaned at 5 or 7 weeks of age; starter feed was available to the pigs from 19 days of age. Their data indicated that 8-week weight was not affected by discontinuing milk feeding at the earlier age although the total consumption of milk solids was decreased and the amount of starter consumed increased. While some wait until the pigs are 3 weeks of age to feed only dry meal (Miller et al., 1963a), others have fed only dry feed when the pigs were 15 days of age (Danielson, 1972; Stanton and Mueller, 1976) or 10 days of age (Scoot, Owen and Agar, 1972). Clark (1978) noted that pigs can be successfully weaned to a dry diet at 14 days of age if they are not held back by a contaminated environment. Lecce, Armstrong and Crawford (1978) tried to determine the optimum age for shifting the pigs from a frequent, liquid feeding regimum to ad lib. dry feeding. They reported that pigs shifted at 9 days of age had markedly depressed rates of gain while those shifted between 14-17 days of age had only a temporary, slight decline in the rate of gain, and pigs 30 days old had no growth check. They also observed that pigs weaned abruptly suffered diarrhea, increased death loss and the longest growth depression. Kenworthy and Allen (1966a) reported that pigs weaned abruptly at 3 weeks of age sufferred temporary malabsorption of fats ans carbohydrates, and increased intestinal fluids which sometimes resulted in diarrhea. They also noted that litters varied in their ability to accomodate the dietary change.

There are wide variations reported on how frequently the artificially reared pigs are fed, ranging from ad lib. to only twice daily. Pigs on the sow nurse approximately every hour (Hartman et al., 1962; Barber et al., 1955); milk let-down lasts only 19-30 seconds (Barber et al., 1955; English and Smith, 1975), and only a small amount of milk is received at each let-down. An automatic feeding device is the only practical way to most closely approximate the natural feeding schedule. The machines can be programmed to feed hourly (Clark, 1978; Brooks and Davis, 1968; Coalson and Lecce, 1970) or every 90 minutes (Danielson, 1968, 1971; Lee et al., 1973; Veum et al., 1973; Zamora et al., 1975; Hendricks et al., 1970; Campbell et al., 1971; Schmidt et al., 1973).

A producer may wish to substitute labor for capital and choose to hand-feed the pigs. Pigs have been artificially reared when fed 6 times daily (Kornegay and Blaha, 1975a,b), 5 times per day (Coalson et al., 1971, 1973; England, Chapman and Bertun, 1961; Wolfe et al., 1975; Catron et al., 1949; Miller et al., 1962b; Matrone et al., 1959), four times daily (Miller et al., 1963a, 1964a; Johnson et al., 1948; Pond et al., 1961, 1971c; Weybrew et al., 1949; Fowler and Young, 1962), three times a day (Cornelius et al., 1973; Drees and Waxler, 1970a; Johnson et al., 1948; Meyer, Bohl and Kohler, 1964; Sewell et al., 1953a,b; Underdahl and Young, 1957; Waxler and Drees, 1972) or twice daily (Braude et al., 1970a; Manners and McCrea, 1963a). Johnson, James and Krider (1948) reported that pigs fed 3 times daily grew as satisfactorily as those fed 4 times per day, and Friend and Cummingham (1964) reported equal performance with piglets fed once or 5 times daily. Berry et al., (1962) concluded that while feeding 3 times per day minimizes time and labor, management can be complicated since over-feeding diarrhea was observed; feeding 7 times daily resulted in better performance due to greater total dietary intake, and no over-feeding diarrhea was noticed. Successful results are also reported when the pigs were fed ad lib. (Becker et al., 1954a; Braude et al., 1970b; Frobish et al., 1969; Pettigrew and Harmon, 1975; Shanklin et al., 1968; Sheffy et al., 1952a). A disadvantage to restricted feeding is that the manager must learn from experience how rapidly to increase the volume fed; overfeeding results in scours and feed wastage, and underfeeding leads to agitation of the pigs and poor performance.

Some researchers gradually reduce the number of feedings per day; for example, a decrease from 6 times daily to 5 (Stothers et al., 1955) or 3 times daily (Catron et al., 1949; Waxler et al., 1966). Lehrer et al. (1949) decreased the number of meals from 8 to 6. Others fed at 2 hour intervals the first 3 days, at 4 hour intervals the next 4 days and at 8 hour intervals the last 2 weeks (Elliot et al., 1975; Scoot et al., 1972).

The pigs are often not fed at regular time intervals; the feedings may be spaced at regular intervals during the day and a slightly longer interval to the night feeding, and no feed during the night (Young and Underdahl, 1951; Coalson et al., 1971, 1973; Johnson et al., 1948; Pond et al., 1971c; Weybrew et al., 1949; Braude et al., 1970a). Some researchers feed a larger amount at the night feeding; Braude et al. (1969a) fed one-third the daily ration at 10 AM and two-thirds at 5 PM.

Even though pigs are fed only a limited number of times per day the feed consumption can be essentially ad lib. (Stothers et al., 1955; Shanklin et al., 1968; Schneider and Sarett, 1966a; Schendel and Johnson, 1962), even if the time per feeding allowed the pig to ingest the meal is limited (Shanklin et al., 1968; Weybrew et al., 1949; Young and Underdahl, 1951), or by feeding so that a small amount of diet is still left in the dish at the next feeding (Kornegay, Haye and Blaha, 1976; Johnson et al., 1948). Menge and Frobish (1976a) reported that essentially ad lib. feeding resulted in greater gain than if the feed was limited to what pigs consumed in a 20-30 minute period, probably due to higher average dry matter intake; DeUriarte and Zimmerman (1978) also reported that average daily gains were significantly lower if milk intake was restricted. Madubuike et al. (1978) reported that the overall performance of piglets fed ad lib. was superior to pigs limited-fed 4 times daily.

The digestive tract of the pig adapts to the stress of infrequent meals and much greater food volumes during short feeding intervals. Manners and McCrea (1963a) reported that by 4 weeks of age, artificially reared pigs had 2.5 times the stomach capacity of sow-reared littermates; Palmer, Teague and Venzke (1965) also reported hypertrophy of the stomach and small intestine of meal-fed pigs. Braude et al. (1970a) compared hourly feeding with twice-daily feeding and reported that, in general, less frequent feeding had a marked effect in increasing the weight of the stomach and small intestine relative to liveweight; Waxler and Drees (1972) reported that in sow-reared pigs the gastro-intestinal tract made up a smaller proportion of the bodyweight.

Braude et al. (1970a) reported that the retention of digesta in the stomach appeared to be an important factor in the digestion of milk protein and regulation of the amount of digesta in the small intestine, as well as maintaining digestive efficiency especially if fed only twice daily. They noted that stomachs of pigs fed twice daily, as compared to those fed hourly, contained a greater amount of digesta 2 hours after a meal although there was little difference in the amount and composition of digesta in the small intestine and cecum. Kidder, Manners and McCrea (1961) compared sow-reared pigs with pigs artificially reared and fed only twice daily and reported that the diet passed through the small intestine more slowly than sow milk.

Allee et al. (1972) reported that for growing pigs, meal-fed pigs had a superior feed efficiency than pigs allowed constant access to feed although there was no significant difference in average daily gain. Braude et al. (1970a) noted no significant effect on rate of gain for pigs fed hourly or twice daily, except at the very low levels of feeding milk solids, although hourly feeding did improve feed efficiency. In contrast, Blaha and Kornegay (1975) compared pigs fed 3 time per day with pigs fed every 90 minutes, with an effort made to equalize intakes, and concluded that the machine-fed pigs had faster rates of gain, increased survival rate and significantly better feed efficiencies.

The feeding frequency should be considered when selecting dietary ingredients. Coalson, Lecce and Jones (1973) reported that for pigs between 14-35 days of age, there was no difference in gain or feed efficiency when a liquid diet, based on milk protein, was fed hourly or 3 times daily or fed as a dry meal; but diets based on soy-flour protein were equivalent to milk protein diets only if fed hourly in liquid form, and feeding it as a liquid 3 times daily or in meal form resulted in significantly poorer performance. Manners and McCrea (1963a) theorized that the difference in feeding frequency may partially explain why sow-reared pigs grow so well on a diet containing an energy:protein ratio wider than that found best with artificially reared pigs fed only twice daily. Berry et al. (1962) reported that regardless of feeding frequency a diet based on lactose and casein was inferior to a modified cow's milk diet, as measured by rate of gain and feed efficiency.

Automatic feeding devices may be programmed to feed amounts to individual pigs on the basis of their weight (Braude et al., 1970a; Coalson and Lecce, 1970; Clark, 1978). With hand-feeding, the volume of feed may also be judged on an individual basis by considering the condition of the pig and how well it consumed its previous meal (Schneider and Sarett, 1966a; Wolfe et al., 1975). Some researchers increased the feed in set increments or gradually increased the amount to a specified level and thereafter, as the pig required more feed, dry feed gradually replaced the milk replacer for the bulk of the diet. In some studies the feed is increased by 5 ml each meal if the pig has consumed all the previous meal and is in good condition (Coalson, Maxwell and Hillier, 1971; Coalson et al., 1973; Berry et al., 1962; Fowler and Young, 1962). Campbell, Brough and Fell (1971) increased the feed by 35 ml per day and Lecce (1971) increased the feed 50-75 ml per day.

The amount fed to the baby pig is usually limited at first to prevent over-feeding diarrhea. The suckling pig usually ingests approximately 50-60 gm of sow's milk the first hour (Coalson and Lecce, 1973a; Donald, 1937b). Twenty-five to 30 ml is often initially offerred as the first meal (Balconi and Lecce, 1966; Fowler and Young, 1962; Pond et al., 1961) when artificially rearing the pigs. Balconi and Lecce (1966) fed 25 ml the first feed and 40 ml per hour for the next 10 hours. Waxler and Drees (1970a, 1972) offerred 90 ml the first feeding and thereafter 120 ml; Fowler and Young (1962) fed 40-50 ml after an initial meal of 30 ml. But the amount may also depend on how frequently the manager plans on feeding. Berry et al. (1962) fed 24 ml per pound bodyweight if the pigs were to be fed 3 times daily and 15 ml per pound bodyweight if fed 7 meals daily.

Total amounts fed per day the first few days vary widely, from 180-200 ml (Campbell et al., 1971; Drees and Waxler, 1970; England and Keeler, 1965; Waxler and Drees, 1972) to 300-480 ml (Waxler et al., 1966). Lecce (1971) based the initial amount on the pig's weight, with small pigs receiving 225-300 ml per day and large pigs 350-450 ml per day the first few days. Coalson et al. (1973) fed the pigs at 7, 14 and 21 days of age 500, 1125 and 1465 ml, respectively. Waxler and Drees (1972) fed 240 ml per meal for a total of 720 ml per day by the end of the third week; Waxler, Schmidt and Whitehair (1966) fed 500-700 ml per day, while Pond et al. (1961) fed 250 ml per meal for a total of 1000 ml per day at 3 weeks of age. Scoot, Owen and Agar (1972) fed 300 ml per kg bodyweight initially to a maximum of 900 or 1500 ml/kg/day. Pond, VanVleck and Hartman (1962) reported that the sow averages 74.6 gm per pig per milk let-down period, for a total of approximatley 1790 gm per day at 3 weeks of age.

The feeding level is also an important consideration when artificially rearing baby pigs. Sow milk is approximately 18-20% solids. When the pig is fed only a few times each day, it is necessary to maintain the solid content of the feed at the highest possible level so that the bulk is minimized. Manners and McCrea (1963a) reported that excess bulk may cause feed refusals and scours; they theorized that if the digestive tract is over-loaded there may be a loss of efficient digestion and absorption. However, Braude et al. (1970a) reported that at too high a level of feeding there may be some breakdown of the regulatory function of the stomach, and the mortality rate appeared to be associated with a very high level of feed the first few days; the clotted digesta was less efficiently retained in the stomach and the increased amount of digesta in the small intestine may be associated with a decreased efficiency of absorption. Braude, Newport and Porter (1970b) reported that at higher levels of feeding total digestive enzyme activity increased at higher levels of feeding but was not influenced by the frequency of feeding (hourly vs. twice daily).

The % total solids in experimental feeding have ranged from 11.5% dry matter (Cornelius et al., 1973), 13.4% (Pond et al., 1961), 15% (Frobish et al., 1967, 1969), 20% (Veum et al., 1973; Danielson, 1971) and 25% (Scoot et al., 1972). Others fed on the basis of dietary solids intake as approximately 5% of bodyweight (Miller et al., 1955; Elliot et al., 1975). While the amount of solids may be gradually increased (Weybrew et al., 1949; Catron et al., 1949), some keep the solids:water ratio constant (Danielson, 1971; Stanton and Mueller, 1976; Veum et al., 1973).

Braude et al. (1970a) reported that as the feed level was increased the growth rate increased although there was some deterioration of feed efficiency. Catron et al. (1949) also noted a decrease in feed efficiency as solids were increased, and the total feed intake increased with an increase in solids. Braude et al. (1970a) reported that with a high level of feeding the growth rate of the artificially reared pigs exceeded that of sow-reared pigs. Jones (1969) noted that the growth rate was different at different levels of feeding and reflected the quantity of milk solids ingested; he also reported that pigs fed 22% solids had weight gains equal to sow-reared pigs from birth through 7 days of age, and better survival and greater gains from birth through 14 days of age. Braude et al. (1970a) compared 12.5% solids to 20% solids, and their data indicated that at the higher level of feeding the pigs had considerably higher growth rates, and exceeded even those of sow-reared pigs. Perry and Lecce (1968) observed the efficiencies of food conversion for the periods of 0-7 days and 0-14 days of age, and the weight gains made over the same periods; they suggested that the combination of a high milk solids content and a smaller total daily volume was more conducive to a greater live-weight gain and lower food conversion efficiencies than a lower milk solids content and a larger volume.

There are many types of diets which have been used to artificially rear pigs, ranging from commercially available prepared canned liquid formulas or dry milk replacers, to complicated, home-made formulas. Perry and Lecce (1962) based diet selection on the basis of having one basic formula which was relatively cheap and did not require extensive formulation or demand time-consuming labor during preparation; their diet was primarily cow's milk with supplementary fat-free powdered milk solids. Most diets are based on cow's milk products, although some research has been done with "synthetic" milks of isolated soybean (alpha-protein) protein (Wahlstrom et al., 1950, 1952; Pond et al., 1961). Data from experiments by Weybrew et al. (1949) indicated that the baby pig, if adequately fed, has much greater growth potential than is ordinarily realized with sow-reared pigs. Schneider and Sarett (1966b) indicated that some differences in the pigs' growth and body composition could be attributed to differences in composition of the formulas fed. Caution must be used when comparing growth rates of pigs in different studies in which liquid diets are used because of differences in dry matter, feed intake and management.

Many diets vary in milk products upon which they are based. Some are based on homogenized cow's milk (Montgomery and Johnson, 1972; Smith and Lucas, 1957a; Young and Underdahl, 1951; Underdahl and Young, 1957; Waxler, Schmidt and Whitehair, 1966; Haelterman, 1956; Meyer, Bohl and Kohler, 1964; Danielson, 1972), casein (Bustad, Ham and Cunha, 1948; Johnson, James and Krider, 1948; Blair, 1963; Lecce, Matrone and Morgan, 1961a; Miller et al., 1961b; Pond et al., 1961), dried skim milk (Catron et al., 1949; Pettigrew and Harmon, 1975; Schendel and Johnson, 1953; Smith and Lucas, 1957a), and whole cow's milk (Kornegay and Blaha, 1975a, b; Cornelius et al., 1973; Lecce, 1971; Matrone, Hartman and Clawson, 1959; Young, Underdahl and Hinz, 1955). Casein may be inferior to whole cow's milk as measured by pig gains and feed efficiency (Berry et al., 1962). The diets are modified or supplemented with a variety of ingredients, primarily vitamins and minerals, and perhaps an antibiotic. In some cases a combination of milk and milk replacer are fed (Danielson, 1972; Montgomery and Johmson, 1972).

Basic, simple home-made recipes are usually based on mixing whole cow's milk with vitamins and minerals, and perhaps whole egg (Young and Underdahl, 1951; Underdahl and Young, 1957; Schendel and Johnson, 1953; Weybrew et al., 1949; Matrone, Hartman and Clawson, 1959; Haelterman, 1956; Coalson, Maxwell and Hillier, 1971). Human infant diets are nutritionally inadequate for the baby pig (Berry et al., 1962; Schneider and Sarett, 1966b), mainly because they are low in protein. Complicated formulas have been fed in research labs with the addition of such ingredients as lard, sugars, antibiotics, combinations of many milk products, cod liver oil, yeast extract, agar, butter, and corn starch (Johnson, James and Krider, 1948; Lecce, 1971; Smith and Lucas, 1957a; Miller et al., 1962b; Pond et al., 1961; Weybrew et al., 1947, 1949; Blair, 1963; Catron et al., 1949; Kornegay and Blaha, 1975a). Manners and McCrea (1963a) reported that a simple, low-fat diet of glucose, dried separated milk and casein, supplemented with minerals and vitamins was adequate, and simulated sow milk (high-fat) diets were not necessary and were so difficult to prepare they were not very practical.

The producer may find home-prepared diets expensive and time-consuming to prepare, and opt for feeding a commercially-prepared diet. Canned, liquid formulas are generally fed to SPF pigs since the diets are sterilized. Schneider and Sarett (1966a) compared one such formula with a diet prepared to more closely approximate sow's milk, especially in caloric density. Both contain skim milk, casein, vegetable fat, lactose, vitamins and minerals. Both diets were satisfactory and pig weight gains equalled those of sow-reared pigs although greater weight gains were acheived with the artificial diet due mostly to a higher caloric density. A powdered milk replacer may be more economical to feed under most farm conditions, however. Commercial, powdered milk replacers reconstituted with water have been fed in several studies (Stanton and Mueller, 1976; Scoot et al., 1972; Grummer, 1954; Kornegay and Blaha, 1975b; Lee, Kauffman and Grummer, 1973; England and Chapman, 1962; Fowler and Young, 1962) and many automatic feeding devices are designed to feed these products. However, not all commercial sow's milk replacers are adequate (Anon., 1973a).

Although it would be adventageous to use enzyme supplements so it would be theoretically possible to feed less expensive protein sources in the baby pig diets, enzyme supplementation is usually of no benefit. One reason for variable reports on the value of enzyme supplementation could be variations in the rate of food passage (Anon., 1957). Lewis et al. (1955) are about the only researchers to find an increase in rate of gain and feed efficiency with the addition of proteolytic enzymes, pancreatin and pepsin, in the diet. Other researchers who have fed diets supplemented with digestive enzymes report no significant effect on average daily gain (Combs et al., 1960; Cunningham and Brisson, 1957b; Maner et al., 1959), protein digestion (Cunningham and Brisson, 1957b; Baird et al., 1976) or digestion of fat and dry matter (Baird et al., 1976). Unsuccessful results have been obtained with supplementation of diets with amylases (Calder et al., 1959; Cunningham, 1959; Cunningham and Brisson, 1957a), pepsin (Calder et al., 1959; Cunningham and Brisson, 1957b; Maner et al., 1961), trypsin (Maner et al., 1961) and proteolytic enzymes (Lewis et al., 1955). Calder, Lodge and Blair (1959) reported that pepsin supplementation even was harmful because it tended to cause or aggravate diarrhea, and may even inhibit the development of the pigs own digestive system. Predigested protein in the diet fails to improve performance (Lewis et al., 1955) and may cause severe diarrhea and death (Cunningham and Brisson, 1957b).

The reported effects of adding antibiotics to baby pig rations are quite variable. The research had been conducted with a variety of antibiotics, levels of antibiotics and ages of pigs. In general, the improvement in growth rate is more consistent and the response greater than for improvements in feed utilization. Wahlstrom et al. (1952) reported that Aureomycin and Chloromycetin stimulated feed consumption and increased weight gains of baby pigs fed an alpha-protein synthetic milk diet. Aureomycin has also been reported to stimulate the growth and increase feed efficiency of piglets in other studies (Wahlstrom et al., 1950; Smith and Lucas, 1957a), although it has no effect on fecal coliforms, lactobacilli or yeast cells (Wahlstrom et al., 1952).

Streptomycin may not have any growth-promoting effect (Sheffy et al., 1952a). Wahlstrom et al. (1950) reported no significant beneficial growth-promoting effects from penecillin or sulfathalidine, although the latter did decrease the number of fecal coliform bacteria. Studies at Iowa State University (Anon., 1973a) indicated that the addition of penecillin to the pig's diet resulted in faster gains, probably because of increased feed intake and a small increase in feed efficiency.

Chlortetracycline supplements have resulted in faster rate of gain with both SPF (Hays, 1973) and pigs artificially reared in nonsterile environments (Hill and Larson, 1955). Iowa State University studies (Anon., 1973a) indicated that chlortetracycline sulfamethazine improved growth rate but did not influence survival. England, Chapman and Bertun (1961) concluded that chlortetracycline exerted growth promoting effects in the absence of disease and may be from a combination of effects upon intestinal microflora and disease protection.

Catron et al. (1949) reported that a combination of terramycin, streptomycin and penecillin were no better than terramycin alone. In contrast, Hays (1973) noted that a 3-way combination of chlortetracycline, sulfamethazine and penecillin increased gains much more than a 2-way combination of penecillin and streptomycin; the 3-way combination, but not the 2-way, was effective in preventing a decreased growth rate when the SPF pigs were moved to a convential environment. Lucas, Calder and Smith (1959a) reported that in pigs between 9 and 26#, a combination of chlortetracycline and procaine penecillin increased growth rate and feed efficiency. Calder, Lodge and Blair (1959) reported that a relatively low level of an antibiotic mixture of chlortetracycline hydrochloride and procaine penecillin tended to decrease the incidence of scours and increased the feed intake and growth rate although feed efficiency was not improved.

Iowas State University studies (Anon., 1973a) indicate that neomycin sulfate improved 3-week weight and survival rates of baby pigs. Harmon, Jensen and Baker (1973) reported that in addition to reported benefits on rate of gain and sometimes feed efficiency of pigs receiving zinc bacitracin, cycloserine and neomycin in the diet, there was also a significantly greater antibody response to bacterial antigens than controls.

The economics of feeding antibiotics may be considered important by many producers. Calder, Lodge and Blair (1959) reported that the economy of liveweight gain was the same whether antibiotics were fed or not, and the value of inclusion depends on the economic return by saving 6 days to reach 40#. Lucas, Calder and Smith (1959a) also reported that antibiotic mixture above 50 mg per pound of feed was not economically justified by saving only 2-3 days, and perhaps 1.5# of feed, between 9 and 26# liveweight.

Diarrhea

Diarrhea has been one of the major drawbacks of artificial rearing. It can be triggered by a multitude of factors, both infectious and non-infectious. The diarrhea may be severe (Bustad, Ham and Cunha, 1948), or mild and transient (Menge and Frobish, 1975; Kohler and Bohl, 1966a; Grummer, 1954; Edwards, 1965; Pond et al., 1961); it may start within a few hours (McRoberts and Hogan, 1944) or a few days after weaning (Coalson and Lecce, 1972; Johnston, 1974b; Kornegay and Blaha, 1975a; Bustad, Ham and Cunha, 1948). Generally, if the pigs survive the first 8 days, the diarrhea is usuallly not a problem (Miller et al., Lecce, Matrone and Morgan, 1961a). Scours are more difficult to prevent and control with small pigs and those which have received little or no colostrum (Kornegay and Blaha, 1975a). Kornegay and Blaha (1975b) also reported that pigs weaned at 96 hours of age were only slightly less susceptible to scours than those weaned at 12 hours of age. Curtis, Rogler and Martin (1969) indicated that larger pigs may be better able to withstand postnatal dehydration than runt pigs.

Pigs which have suckled resist the development of diarrhea (Bustad, Ham and Cunha, 1948) while those which have not nursed usually rapidly develop severe scours when artificially reared in a nonsterile environment (Bustad, Ham and Cunha, 1948; Campbell, Brough and Fell, 1971; Lecce, Matrone and Morgan, 1961a) even with strict sanitary conditions. Partly this is due, in very young pigs, to the possibility of the bacteria being absorbed by the pinocytosing gut cells (Lecce and Morgan, 1962; Lecce, Morgan and Matrone, 1964; Staley, Jones and Corley, 1969; Corley, Staley and Jones, 1973), although it is not necessary for the bacteria to invade the intestinal epithelium to produce diarrhea (Waxler, Christie and Drees, 1971). Circulating antibodies provide little protection from colibacillary diarrhea (Corley, Staley and Jones, 1973).

Cunningham and Brisson (1957c) observed a significant decrease in digestibility of dry matter, protein, fat, ash and carbohydrate in scouring pigs; the interference with absorption of nutrients plays at least some role in the pathogenesis of colibacillosis (Christie and Waxler, 1973b). Scours depletes the pig of electrolytes and B-complex vitamins (Lehrer, Wiese and Moore, 1952), and may affect the development of the brush border of the intestinal epithelial cells, which in turn may affect the development of digestive enzymes and absorption of nutrients (Campbell, Brough and Fell, 1971; Waxler, Christie and Drees, 1971). Jones (1963) reviewed many of the nutritional problems of scouring pigs, such as subnormal absorption of amino acids and deficiencies of water-soluble vitamins.

There are many non-infectious causes of scours in the pig, such as physiological malfunction of the stomach (White et al., 1969), soured milk (Braude et al., 1970a), impurities in the water (Montgomery and Johnson, 1972), and improper diet (Smith and Lucas, 1957a; Lecce and Coalson, 1973). Montgomery and Johnson (1972) noted that not all milk replacers are adequate and scouring problems may arise. An abrupt change in diet can lead to digestive upsets, which in turn provides favorable substrates for the proliferation of bacteria in the gut which may be pathogenic.

A change in environment brings pigs into contact with new strains of bacteria, and the level of hygiene has a pronounced influence on the incidence of fatal gastro-enteropathies (Svendsen et al., 1975). Manners and McCrea (1963a) also note that a high standard of hygiene allows the pigs to survive a period of poor feed utilization without ill effects. While nursing the sow, the pig is protected by colostral and milk antibodies (Kohler and Bohl, 1966b; Rejnek et al., 1968) but when weaned to artificial diets, it no longer receives this protection.

The pig is born with an essentially sterile gut (Wilbur et al., 1960; Larson and Hill, 1955; Kvarnfors and Mansson, 1972) but within 1-3 days there is a high count of micro-organisms in the feces (Kvarnfors and Mansson, 1972; Wilbur et al., 1960). Lactobacilli are usually the predominant micro-organism in healthy pigs (Kenworthy and Crabb, 1963), but there is also a moderately high coliform count of mostly non-hemolytic strains (Campbell, Brough and Fell, 1971). Pathogenic Ecoli are widely distributed throughout the swine population and occur in feces from healthy animals (Armstrong and Cline, 1977; Barnum, 1971; Kohler, 1972).

The relatively high pH of the baby pig's stomach the first few days may permit Ecoli, streptococci and Clostridium welchii to proliferate in it, and this may be part of the reason Ecoli scours are the most prevalent in pigs less than 7-10 days of age (Armstrong and Cline, 1977; Barnum, 1971; Coalson et al., 1973; Kohler, 1969; Morse et al., 1974). Factors affecting the proliferation of micro-organisms vary according to the age of the pig (Barnum, 1971; Corley, Staley and Jones, 1973; Drees and Waxler, 1970a; Kohler, 1969). Armstrong and Cline (1977) reported that dietary components may play a role in fluid accumulation in the small intestine and may be a predisposing factor to diarrhea.

Kohler (1972) reviewed much of the literature on colibacillosis of baby pigs and summarized the factors influencing the development of of colibacillosis as being: environmental and dietary stressors; adequate supply of suitable milk; size and vigor at birth; number of Ecoli in immediate surroundings; pre- or co-existant infections with other microbial agents; possible influence of other species of competitive organisms in intestinal flora; natural or inherent resistance; chilling; and relatively high stomach pH. He noted that the baby pigs vary in their susceptibility to Ecoli infection and enterotoxin, and susceptibility may be increased by prematurity at birth, and various stressors that produce or prolong gastro-intestinal stasis; the pig is less susceptible if appropriate antibodies derived from colostrum or milk are constantly present in the intestinal lumen. He concluded that with diarrhea and the continued loss of fluids and electrolytes, the pig becomes dehydrated and acidotic; as a result there is hemoconcentration, inanition and failure of the normal parenteral defense mechanisms to control microbial invasion and systemic infections, and failure of vital metabolic processes.

The Ecoli may attach to the villous epithelial layer (Arbuckle, 1972; Nagy and Penn, 1975), especially in the upper small intestine (Kenworthy and Grabb, 1963), and resist being flushed from the gut (Arbuckle, 1972). The attachment enables the toxins to exert a greater deleterious effect as compared to what would occur if the toxins were produced in the gut lumen and diluted with intestinal contents (Arbuckle, 1972). Not every sow's colostrum has the necessary components to prevent the adhesion (Nagy and Penn, 1975), and serum or colostrum from nonvaccinated sows may have no effect on pig survival over those pigs not given any preventative treatments (Svendsen and Wilson, 1971). Ecoli scours results in degeneration and exfoliation of the microvilli (Staley, Jones and Corley, 1969; Drees and Waxler, 1970b).

The pig may die before it develops any typical clinical signs of collibacillosis (Kohler and Bohl, 1966a); recovery or death usually occurs 4-5 days after the onset of the disease (Barnum, 1971; Moon et al., 1966) and pigs which survive often do not gain well for several days (Kohler, 1969) and may even remain chronically unthrifty and suffer from intermittent diarrhea (Embleton, 1971). The pigs may develop a local immune response (Corley, Staley and Jones, 1973) and Lecce, Matrone and Morgan (1961a) reported that coincident with the start of the pig's serum protein development at approximately 1 week of age, medication in the feed was no longer necessary. Armstrong and Cline (1977) reported that pigs fed a milk replacer diet with an antibiotic gained faster and sufferred less diarrhea than pigs fed a corn-soybean meal diet; they concluded that Ecoli may be unable to proliferate in the gastro-intestinal tract of pigs fed the milk replacer diet, possibly due to the antibiotic, physical form of the diet or the volume consumed.

Some researchers with-hold feed up to 12 hours after the pigs are removed from the sow to assure initial intake of fresh diet since it is so conducive to bacterial growth (Anon., 1973a; Danielson, 1971; Pond et al., 1961). Many researchers limit the amount of diet fed the first few days to limit the possibility of scours from overfeeding (Schendel and Johnson, 1962; Miller et al., 1955; Braude et al., 1970a; Schneider and Sarett, 1966a; Scoot, Owen and Agar, 1972; Pond et al., 1961).

To reduce the incidence and control scours, the number of pathogenic strains in the environment must be minimal, the active proliferation of pathogens in the upper gastro-intestinal tract must be reduced, and the resistance of the host must be maximized through immune mechanisms. The primary preventative measure is strict sanitation and the success of rearing decreases with the number of germ strains in the environment (Sickel, 1972). When artificially reared in an ordinary farm environment, the pigs may be disease-free but they will not be germ-free. Care must be taken to prevent contact with other swine and exposure to diseases (Young, Underdahl and Hinz, 1955). Failure to handle even one pig properly can result in disease in that animal from proliferation of pathogenic micro-organisms, thus the disease can spread to all other pigs the ill animal contacts.

Clark (1978) reported that researchers at Central Soya washed sows twice daily 3-4 days before farrowing when planning to artificially rear the baby pigs. To keep bacterial growth in the room at a minimum Kernegay and Blaha (1975a) reccommended that the room temperature be kept at 70°F with supplemental heat for the pigs. An argument in favor of caging the pigs individually is that pigs in groups of 6 generally had higher counts of fecal organisms (Wilbur et al., 1960). As a preventative measure, Pond et al. (1961) injected each pig intraperitoneally with 1 ml antibiotic and 15 ml of a porcine gamma-globulin preparation. While researchers all agree that cleanliness of feeding equipment is necessary, there is great variation in the frequency with which it is done. Many wash the pans after each feeding (Coalson and Lecce, 1970; Lecce, 1971; Schendel and Johnson, 1962). Berry et al. (1962) provided a clean pan at each meal when feeding 3 times daily, but changed pans only once daily when feeding 7 times daily. Beatty (Montgomery and Johnson, 1972) washed the feed pans twice daily the first week and thereafter once daily. Haelterman (1956) reported that if the amount of feed is regulated so all was consumed before the next meal it was not necessary to clean the pans more frequently than once every

2-3 days. The pans may be washed by hand with hot water and household detergent (Schendel and Johnson, 1962) or machine-washed (Montgomery and Johnson, 1972); the Auto-Sow device automatically removes the pans and washes them in hot chlorinated detergent sprayed under pressure and rinsed with cold water to leave them practically sterile (Coalson and Lecce, 1979).

Varying degrees of success have been reported for different treatments for scours and the cause of the scours is probably the main reason results vary. Restricting the diet when scours develops may be of benefit (Berry et al., 1962; Blair, 1963; Miller et al., 1955; Fowler and Young, 1962). Edwards (1965) reported that a mild scours was controlled without antibiotics by replacing 2 meals with either a Kaolin and glucose-Ringer (50%) solution, or a glucose-Ringer (50%) solution. Weybrew et al. (1949) successfully controlled a yellow scours by increasing the dietary level of a mineral supplement.

There have been successful results by treating the pigs with sulfathalidine (Lehrer, Wiese and Moore, 1952), chlortetracycline (Pond et al., 1961) and chloromycetin (Lecce, Matrone and Morgan, 1961a). Glawischnig (1972) reported that the most practical treatment of diarrhea was a combined oral application and dosage of therapeutic drugs (neoterramycin, chloramphenicol, dihydrostreptomycin and furadolidone) and a swine gammaglobulin preparation.

Prophylactic agents tried without success include cultured buttermilk, finely ground beet pulp, soil, and cultured lactobacillus acilophilus organism (Anon., 1973a) and cellulose (Kornegay and Blaha, 1975b). Therapeutic agents tried without success include penecillin, sulfathalidine, sulfamethazine and Kaopectate (Bustad and Cunha, 1947), this would indicate that the diet was more likely the cause of the diarrhea rather than micro-organisms, unless the pathogens were resistant to these agents. Bustad and Cunha (1947) reported that bacterin was of no benefit in treating scours, but their test diet included sucrose; Smith and Lucas (1957a) reported that with a diet containing sucrose, the scours were unaffected by modifying the solids level, antibiotic level, by changing feeding equipment or restricting dietary intake. Kornegay and Blaha (1957a) reported that antibiotics were ineffective, although Kaopectate, milk of bismuth and milk withdrawl were effective in treating certain cases of diarrhea; Bustad, Ham and Cunha (1948) also reported that Kaopectate initially increased the consistency of watery feces but failed to entirely relieve the scours.

TRIALS 1 - 5

GENERAL PROCEDURES

Animals: Pigs from the University herd were allowed to suckle at least 12 hours before removed from the sows. In Trial 1, the pigs were crossbred (Hampshire x Duroc); in Trials 3 and 5 the pigs were Duroc; in Trials 2 and 4 the pigs were Yorkshires.

The majority of the pigs chosen were those judged as having poor chances for survival, i. e., orphans, runts, small pigs in overflow litters, injured, pigs from poor-milking sows, or pigs from extremely small litters where it was not economical to feed the lactating sow. A few pigs which were several days old and not doing well on the sow were also weaned and artificially reared.

Housing and Equipment: The animals were housed in a 20' x 30' room. Artificial light was provided continuously. The pigs were not in an isolated environment; there was much traffic through the room although direct contact with the pigs was avoided. The conditions were not sterile but efforts were made to minimize exposure to possible pathogens. An overhead exhaust fan was operated when judged necessary for good air quality. There was no attempt to maintain a constant relative humidity.

The room was not free from drafts or temperature changes; the 2 windows were covered with plastic and the tops, rears and ends of the cages were covered to minimized drafts. When the pigs were observably being chilled, clean rags were provided for the pigs to lay on and avoid drafts coming up through the screened floors. During one trial, when the automatic feeding device was not used, the fronts of the cages were also covered.

The room temperature was difficult to control and fluctuated several degrees during a 24 hour period, and the draftiness of the room compounded this problem. Part of the problem was due to the large size of the room and the high ceiling; also, on several occassions the doors to the room were inadvertently left open. A thermometer was kept by the pigs and this reading was often $10^{o}F$ different from the wall thermometer reading; occassionally someone would read the wall thermometer and lower the thermostat, resulting in chilled pigs.

Heat was provided by a gas heater hung from the ceiling, and the amount of outside air drawn into the heater could be adjusted; heating pads were hung from the rear of the cages and raised the temperature at the rear of the cages by about $5^{o}F$. There was an $8\text{-}10^{o}F$ difference in temperature between the top and bottom rows of cages. The temperature at the pigs' level was initially attempted to be maintained at approximately $90^{o}F$ and gradually reduced, but always maintained so that the smallest pigs were comfortable.

The Mini-Mor Pig Brooder is made up of a frame, cages with cups and an automatic traveling unit. The frame holds the individual cages in 2 rows, with 12 cages per row and a litter tray below each row of cages to catch wastes. The individual wire cages are 2' x 1' x 1'; the feed cups are at the front end and access doors at the rear. Each cage is supplied with 3 cups: liquid formula cup, water cup and creep feed cup.

The automatic feeding unit travels on top of the frame; it dispenses feed to the top row of pigs as it travels in one direction and feeds the bottom row after it reverses, and makes one cycle per hour. The type and amount of feed and water dispensed to individual pigs is controlled by a series of rivets on the control bar and microswitches on the feed unit; by adjusting the cams the length of time the feed augers run may also be adjusted. The traveling unit has 3 plastic containers, to hold the milk replacer, water and creep feed; the water passes through heaters before being dispensed. The dry milk replacer is dispensed simultaneously with water into the liquid feed cup; mixing is not complete but the pigs mix the formula as they eat. The machine can be programmed to feed dry milk replacer plus water, or dry milk replacer only in the liquid formula cup.

Management: The pigs were weaned from the sows in the late afternoon and had been observed nursing at least once. The pigs were placed in the warmer top row of cages; when this row was full and younger pigs were to be added, the entire top set of cages and pigs were moved to the bottom row and the new pigs placed in clean cages on the top row.

If necessary to re-use a cage in which a pig had died, the cage and feed cups were thoroughly washed and disinfected as much as possible. The pigs were weighed at birth, when weaned from the sows, and at weekly intervals; weights were taken in the late afternoon and before the afternoon meal in Trials 4 and 5. Pigs received 1.5 cc intramuscular injections of iron dextran by 3 days of age. When the pigs were first added, approximately 30 ml of diet and/or electrolyte solution was in the feed cups. The dishes were usually washed during the night check the first day since the pigs had often stepped in the cups and had gotten them dirty. Pigs which had eaten were then programmed to be fed automatically every hour when designated, and all pigs received fresh diet and electrolyte solution.

The feed cups were washed at least once per day. Since the cups could not be removed, only warm water was used because the pigs usually tried to drink whatever was in the cups. The litter trays were generally scrubbed with hot water and a wire brush daily since odors rapidly built up; an absorbent material was not practical in the trays because such a large volume of water passed into the trays when cleaning cups. Flies were a problem unless the room was sprayed every few days. Between trials the cages, frame and litter trays were thoroughly scrubbed, disinfected and set in sunlight. There were usually several weeks between trials while equipment was left idle.

When diarrhea occurred, a variety of substances were used: Pepto Bismol, Kaopectate, Gentamicin, electrolytes, chloramphenicol, as well as removing the milk replacer, but not electrolytes, for 8-18 hours. All pigs which died were taken to the University veterinary school for necropsy. Pigs were treated as necessary for cuts (Furazone, Vioform), swollen joints (Lincomycin, Tylan 50) and abscesses (Combiotic). Some male pigs were castrated while still on trial while others were not castrated until after weaned from liquid diets.

Diets: Water was offerred to the pigs only in Trial 1 from birth, otherwise it was offerred from approximately one week before they were to be weaned from the liquid diet. The milk replacer container on the automatic feeding device was filled twice daily. The feeding device heated water to approximately 40°C and diets fed by hand were mixed with hot water and fed at approximately 40-45°C. Electrolyte solutions were fed cold or at room temperature.

The diets used were as follows:

Diet A: Nursing Melk fed hourly.

Diet B: Nursing Melk mixed 3:1 with dried skim milk powder, fed hourly.

Diet C: SAM meal fed hourly + Pig 95 fed 3 times daily (Trial 4).

SAM meal + Pig 95 both fed 3 times daily (Trial 5).

Diet D: SAM meal fed hourly + pig 95 and Pig 45 fed 3 times daily.

Diet E: Pig 45 + Pig 95 both fed 3 times daily.

Nursing Melk (Cadco, Inc.) is a commercial milk replacer with a guaranteed analysis of crude protein not less than 20.00%, crude fat not less than 15.00% and crude fiber not more than 0.25%. It also is medicated with a Neomycin base at 227.5 gm per ton, equivalent to 227.5 mg Neomycin base per gallon of reconstituted milk replacer.

Pig 45 (Triple "F", Inc.) is a commercial milk replacer with a guaranteed analysis of crude protein not less than 30.00%, crude fat not less than 20.00% and crude fiber not more than 0.50%. Pig 45 is not medicated.

Electrolyte solution A, "Glycolyte" (Eaton Veterinary Laboratories), contains sodium chloride, potassium chloride, sodium citrate, Maltrin-10, saccharin and glycine. It is mixed at 65 gm per 2 quarts water.

Pig 95 (Triple "F", Inc.) is a commercial sow milk supplement containing vitamins, amino acids, minerals, elctrolytes, glucose and lactose.

SAM milk pellets and meal (Triple "F", Inc.) has an analysis of crude protein 25.46%, crude fat 10.34% and crude fiber 0.86%.

The creep feed was s standard University corn-soy creep ration (S-134B) and contained Mecadox. The calculated analysis is crude protein 18.3%, calcium 0.74%, phosphorus 0.64% and lysine 1.09%. The ration was in crumbles-form.

Scales of Feeding: With the automatic feeding device it is possible to feed a volume and frequency similar to pigs nursing naturally. The machine was programmed to feed approximately 5 gm Diet A or 6.2 gm Diet C mixed with approximately 16 ml of water, initially, every hour. The feed was increased by the same amount when the pigs were judged as being able to handle the additional feed without any problems. Often the pig was given additional feed for only part of a 24 hour period until it was able to consume the additional amount all the time.

During Trials 4 and 5 the pigs were hand-fed 3 times per day, at 8 A. M., 4:30 P. M. and 9:00 P. M., approximately the schedule a producer could acheive by observing pigs before and after chores and at night when the farrowing house would be checked. Initially the hand-fed pigs were fed a limited amount and left hungry; the amount was increased based on observation of the pig's condition and how well it ate the previous meal. Pig 95 was usually fed first so that the pigs would fill up on this and not tend to overconsume the milk replacer. With hand-fed pigs it was important to follow an established schedule and feeding sequence since the pigs rapidly learned the time of feeding and in what order they were fed; any deviation from routine upset the pigs. Dry creep feed mixed approximately 5:1 with dry milk replacer was initially offerred when the pigs weighed 6-8#, or around 3 weeks of age.

The machine fed Diets A and B theoretically at a level of 37.1% solids; however so much diet stuck to the feeding tubes the solids level was usually much lower than this. The SAM meal was much less of a problem with sticking, but it weighed less on a volume basis and the feeder operated on a timer; thus the pigs were fed at a level of approximately 29.9% solids. Diet C was fed at 14.0% solids initially; however the solids content was increased to 27.9% when the pigs were 2.5 to 3 weeks old and were growing slowly. Diet E was fed at approximately 18.0% solids.

Weaning from Liquid Diets: In the first 2 trials the pigs were weaned to an elevated floor pen with a screened floor; heating pads were placed in one corner of the pen. Creep feed with a little milk replacer powder mixed in was available from feeders and one bowl-type waterer was available. In the last 3 trials the pigs were weaned directly to the nursery.

The pigs were usually weaned on a weight basis rather than strictly by age. The pigs were to be weaned when they weighed at least 10#; however, in the first trial difficulties arose and the pigs were weaned much earlier than this. In subsequent trials, some pigs usually grew much faster than the others and outgrew their cages; these pigs and any pigs close to that size and weighing at least 10# were also weaned; the other pigs were weaned in groups of 4-5 as they reached weaning weight. Ideally the pigs had been observed eating some creep feed for a few days before weaning them from the liquid diets.

Plan of Trials: The basic procedures were based on what could be acheived in an on-farm situation. Many problems arose and the trials were modified as the various situations demanded. No digestion studies or feed efficiencies were calculated due to large feed wastage and scouring of pigs.

PROCEDURES OF INDIVIDUAL TRIALS

Trial 1: Nine pigs were weaned at 2 days of age from a hypogalactic sow. The other 9 pigs were small pigs from large litters and were between 12-24 hours old; 1 of these was splay-legged and another was severely cut. These 9 pigs were added 10-12 days after the first 9 pigs were started. The average age and weight the pigs were weaned from the sows were 2.4 days and 2.4#.

All pigs were to be fed Diet A and water on an hourly basis; electrolyte solution A was fed when pigs were scouring and when the second set of pigs were first weaned from the sow. Pepto Bismol and Kaopectate were also used to control the diarrhea.

Trial 2: The average age and weight the pigs were weaned from the sows were 3.2 days and 2.8#. Of the 25 pigs used, 5 were runts; 1 of these was only 0.9# at birth, another was badly injured and 2 were weaned from the sow at 9 and 16 days of age when they were only half as large as their littermates. Three pigs were surplus pigs in large litters and 7 pigs appearred to be healthy and of good size. The other 9 pigs were sick or injured and judged as having poor chances of survival if left with the sow.

The pigs were to be fed Diet A hourly. Electrolyte solution A was available when the pigs were first weaned from the sow and was fed while the pigs were scouring. Pigs which were scouring were washed if needed. Diarrhea was treated with Gentamicin, PeptoBismol, Kaopectate, Kaopectate plus chloramphenicol, and combiotic.

Trial 3: Eighteen pigs were weaned from the sows at an average age of 1.3 days and 2.6#. Two of the pigs were very small runts, one of which was scouring. Nine pigs were weak, sick or injured and 7 appearred to be healthy, good-sized pigs. The pigs were fed Diet B hourly; SAM pellets and creep feed were hand-fed. Scouring pigs were treated with Gentacin. Electrolyte solution A was available when the pigs were weaned from the sow and when scouring. All pigs were given a second iron injection when they were about 21 days of age as well as injections of Bo-Se (a selenium-Vitamin E compound) and Vitamin B-complex.

Trial 4: In the first part of this trial 8 pigs, the largest and smallest males and females from 2 litters, were weaned at 1 day of age and fed either Diet C or D. The pigs fed Diet C were also given Pig 95 3 times daily after the second day when it was observed that these pigs were rapidly losing condition. The large male and female fed Diet D averaged 3.4#; small male and female pigs fed Diet D averaged 2.0#. Large pigs fed Diet C averaged 3.0# and small pigs fed Diet C averaged 2.7#. Eleven other pigs were fed Diet D. All 19 pigs averaged 2.2# at birth and when weaned from the sows at an average age of 2 days. Of these 11 pigs, 5 were runts but appeared healthy. Five were sickly runts, 4 of which had lost weight since birth; 1 of these was weaned from the sow at 9 days of age and 2 others at 5 days of age. The eleventh pig was small but healthy and was weaned from the sow at 3 days of age. Overall in Trial 4, the average age and weight the pigs were weaned from the sows was 2 days of age and 2.9#.

In the second part of Trial 4, 14 healthy pigs, with an average birth weight of 2.6#, were weaned from the sows at 2 days of age and an average weight of 2.8#. All of these pigs were fed Diet D. Diarrhea was treated with Gentacin or chloramphenicol.

Trial 5: The 22 pigs were weaned from the sows at an average of 0.9 days of age and an average birth weight of 3.0#. Eight pigs with an average birth weight of 3.3# and an average weaning weight of 3.4#, were weaned from sows at 1 day of age and fed Diet C 3 times daily. The other 15 pigs averaged 2.7# at birth and 2.8# at 0.7 days of age when weaned from the sow and were fed Diet E 3 times daily. Creep feed, mixed 5:1 with SAM meal, and SAM milk pellets were available when the pigs were approximately 3 weeks of age.

Six of the pigs were almost totally crippled and 6 others partially crippled by what appeared to be contracted tendons in the feet; of these 12 pigs 2 were also scouring when weaned from the sow, 2 were runts, one of which was severely lacerated, and the other appeared to be healthy except for the deformed legs. Of the remaining 10 pigs, 6 appeared to be healthy, 2 were scouring and 2 were small runt pigs.

Scouring pigs were treated with Gentacin; pigs with swollen joints were treated with Tylan 50 and Lincomycin. One pig with an infected tail stub and another with a snout-whisker follicle infection were given combiotic injections for 1-2 days. Feed was available when the pigs were first weaned from the sow and the amount was limited slightly the first 2 days to adjust the pigs to the feeding schedule and prevent over-feeding scours.

RESULTS, OBSERVATIONS AND DISCUSSIONS

Trial 1: Five of the 18 pigs died for a total of 27.8% mortality; the average age of death was 3.5 days and 2.6 days after weaned from the sow. Of the pigs which died, one was the one which was severely cut, one squealed constantly and died within 24 hours, and 2 were too weak to eat.

The fifth pig died of severe edema of the entire body. The edema was first noticed around the eyes about the fourth day and developed rapidly; the body and limbs were so swollen within 24 hours the pig could not walk and even squealing appeared to be difficult. Swallowing was difficult although the pig was not anorectic, and the pig continued to scour. Pressure sores developed on the legs from the inability of the pig to rise and walk. After 2 days with no change in condition the pig was given an antihistamine and antibiotic injection; the antihistamine injection was repeated 8 hours later and seemed to aid respiration. The pig was a week old at this time and weighed 2.5# from a birth weight of 1.8#; however the pig died the following day, apparently of suffocation. One of the pigs which survived also exhibited slight edema, particularly in the hind limbs, about the sixth day; this pig had difficulty walking and developed sores on the hocks and dewclaws.

Diarrhea was not prolonged or severe in the 9 littermate pigs which were weaned at 2 days of age. However, diarrhea was persistant in all the other pigs and did not respond to treatment. Kaopectate has been shown to be effective occassionally in treating certain cases of diarrhea (Kornegay and Blaha, 1975a) although it may also increase the consistency of watery feces but not entirely relieve the diarrheic condition (Bustad, Ham and Cunha, 1948). There were many problems with the automatic feeder and the pigs were fed very irregularly, which could have been a major factor in the diarrhea. The pigs also acted chilled much of the time and this also may have affected the scouring incidence. The scours caused much skin irritation and the skin around the buttocks became very raw. When necessary, the pigs were washed with mild soap and warm water, dried and ointment applied to the skin.

The pigs were poor in appearance with dry, rough haircoats. Many had a sticky brown exudate around the eyes which occassionally glued the eyelids together. Most of the pigs developed sore feet and had difficulty standing on the screened floors. Weybrew et al. (1949) also noted that some pigs developed sore feet on screens although the pigs usually adjusted. At one point many of the pig's tail and ear-notch scabs broke open and bled slightly; ointment was applied to these sores.

Creep feed, mixed 5:1 with dry milk replacer, was first introduced when the pigs were 8 days of age since the pigs were fed the liquid diet irregularly. The pigs were weaned at an average of 27.8 days and 6.8#. The pigs remained in the raised floor pen approximately 4 weeks before being moved to the nursery.

The pigs varied in growth responses although all gained weight, even one which was losing weight when weaned from the sow. Littermates varied in their growth response. Four pigs which survived the persistant diarrhea had lower average daily gains than pigs not suffering from diarrhea. The pigs continued to gain well after they were weaned to solid food. The growth curve is not linear (Fig. 1); however, the curve is nearly linear up to 4 weeks of age, and

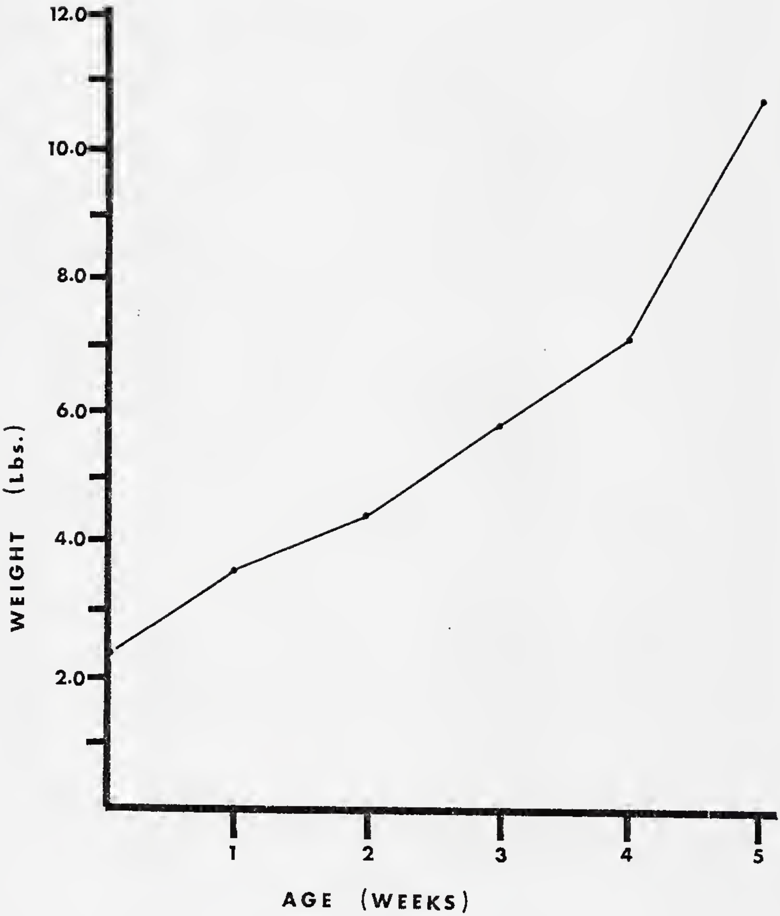

FIGURE 1. Average growth curve of pigs which survived Trial 1.

then the slope changes in another linear direction.

Trial 2: Fourteen of the 25 pigs died for a total of 56.0% mortality; the average age of death was 9.6 days, 8.3 days after being weaned from the sow. Of the pigs which died, 2 were extremely edematous as in the first trial. However, the swelling did not occur until the seventh and 17th. day; another pig also swelled the 7th. day and remained badly swollen for 4 days then gradually returned to normal. Another pig which swelled and later recovered developed an umbilical hernia. Antihistamine injections 2-3 times daily seemed to relieve the edema somewhat.

Of the other 12 pigs which died, 3 were pigs which had been injured by the sow, 1 was the extremely small runt, 4 were scouring or ill when weaned from the sow. Two were littermates which never ate much feed and became weak, unco-ordinated and eventually died. Another runt was scouring severely, developed an umbilical hernia and appeared to die in extreme pain at 13 days of age. Another runt never developed prolonged or severe diarrhea and was doing well although it did sprain 2 legs while playing; this pig suddenly went into a coma and died when 6 weeks of age and 13.0# and ready to be weaned.

All pigs were afflicted with severe and prolonged diarrhea and no treatment appeared to be of much benefit in reducing the severity or incidence. The Diet A was modified by adding dried skim milk in proportion of 1:1 for 2 days; the pigs became constipated so the amount of dried skim milk was reduced over the next 2 days to a final ratio of Diet A:dried skim milk 3:1 (Diet B).

The pigs in this trial also had the brown exudate around the eyes. Two pigs developed what sounded like fluids in the lungs and an antihistamine injection seemed to aid the breathing somewhat.

There were numerous problems with the machine feeding irregularly. The main problem was the dry milk replacer sticking to the feeding tubes and clogging them. The machine would continue to dispense diet and created a further mess. The appearance of the pigs was poor, as in the first trial. The pigs were weaned at an average of 40.2 days and 13.2#. The average growth curve appeared to change slope when the pigs were about 3 weeks of age (Fig. 2) although the pigs differred in their individual growth rates. Two pigs which were in a weight-losing condition when weaned from the sow recovered and gained well; only 2 pigs lost weight during part of the trial and that was when the pigs were swelled or scouring. Most pigs made poor or no weight gains while scouring.

Trial 3: Four pigs died for a total of 22.2% mortality; the pigs died at an average age of 8.1 days, 7 days after weaned from the sow. Of the pigs which died, necropsy results indicated 1 had large numbers of Ecoli and Salmonella; Embleton (1971) reports that Salmonella enteritis has scouring as the main feature, followed by chronic unthriftiness due to progressive necrosis of the bowell wall. Another pig was found to have Ecoli and Streptococci. Both these pigs were sick when weaned from the sows, had severe diarrhea, lost weight and died within 6 and 2 days, respectively. Of the other 2 pigs which died, one was found to have enteritis and much swelling around the head and neck; the other pig swelled severely on the 4th. day and remained badly swollen for 16 days although the degree of swelling fluctuated slightly day to day. When the swelling decreased, the amount of antihistamine injected was decreased but the swelling often then worsened. The pig continued to scour and retained its appetite although it could not move. Upon necropsy there was pleuritis, anemia so severe the blood failed to clot and severe edema of all parts and organs of the body; the subcutaneous edema was as much as a half inch thick.

Nine of the 14 pigs which lived also developed the edema condition and ¼ cc injection of Bo-Se or vitamin B-complex was of no benefit. The edema started between 3-6 days (6 pigs) or 8-9 days (3 pigs); with 2 of the pigs, the swelling was slight for a few days then suddenly worsened the 8th. day. The pigs sometimes fluctuated in the degree of swelling; some pigs were badly swollen for only 2-3 days, 2 others remained badly swollen for over 2 weeks.

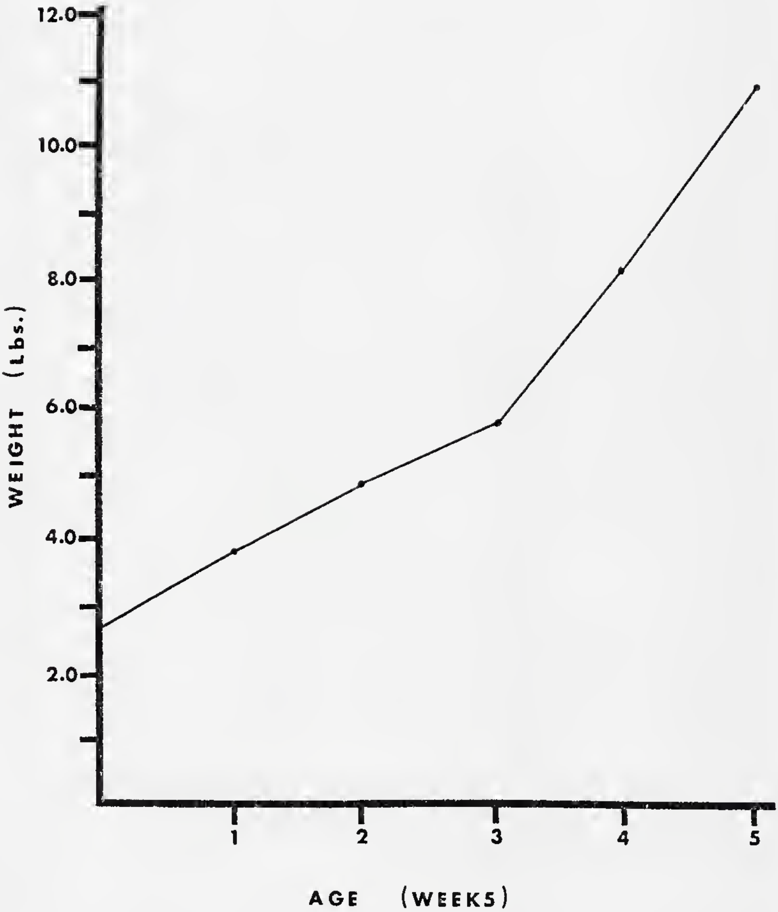

FIGURE 2. Average growth curve of pigs which survived Trial 2.

Antihistamine injections were given 3 times daily in amounts depending on the degree of swelling. Often traces of swelling could be detected for 1 week or more after the pigs recovered. The pigs often developed sores on the legs since they could not move and laid in their food cups for long periods of time. The edema seemed to afflict only 2 litters; one other pig also swelled but its littermate died before any edema could be observed.

All but one of the pigs were scouring within 12 hours after being weaned from the sows but a 2-day treatment with Gentamicin seemed to be beneficial in clearing up the diarrhea. Some pigs also scoured approximately 2 weeks later when there were problems with the feeding device and feeding was irregular. The pigs did not need to be washed because the diarrhea did not seem to be irritating the skin.

Pigs which were losing weight when weaned from the sows regained the lost weight and grew well. Pigs with the edema grew slowly while swollen. In Fig. 3 it can be seen that the acceleration in growth occurred when the pigs averaged 3 weeks of age. The pigs were weaned at an average of 35.7 days and 12.1#.

Trials 4: In the first part of Trial 4, 14 of the 19 pigs died for a total of 73.7% mortality. Of the large and small pigs from the 2 litters, 3 of the 4 pigs fed Diet C died while none of the 4 pigs fed Diet D died. However, the overall mortality of pigs fed Diet C was 75.0% and Diet D 73.3%. The pigs died at an average age of 8.1 days, 5.6 days after weaned from the sows. Of the pigs which survived, the average age and weight the pigs were weaned from the liquid diets was 38.4 days and 16.2#.

In the second part of the trial, 3 of the 14 pigs died at an average of 13 days for a total of 21.4% mortality. The surviving pigs were weaned at an average age and weight of 36.1 days and 14.7#.

The overall mortality of Trial 4 was 51.5% and the pigs died at an average age of 9.1 days, 6.6 days after weaned from the sows. Surviving pigs were weaned from liquid diets at an average age and weight of 36.8 days and 15.2#.

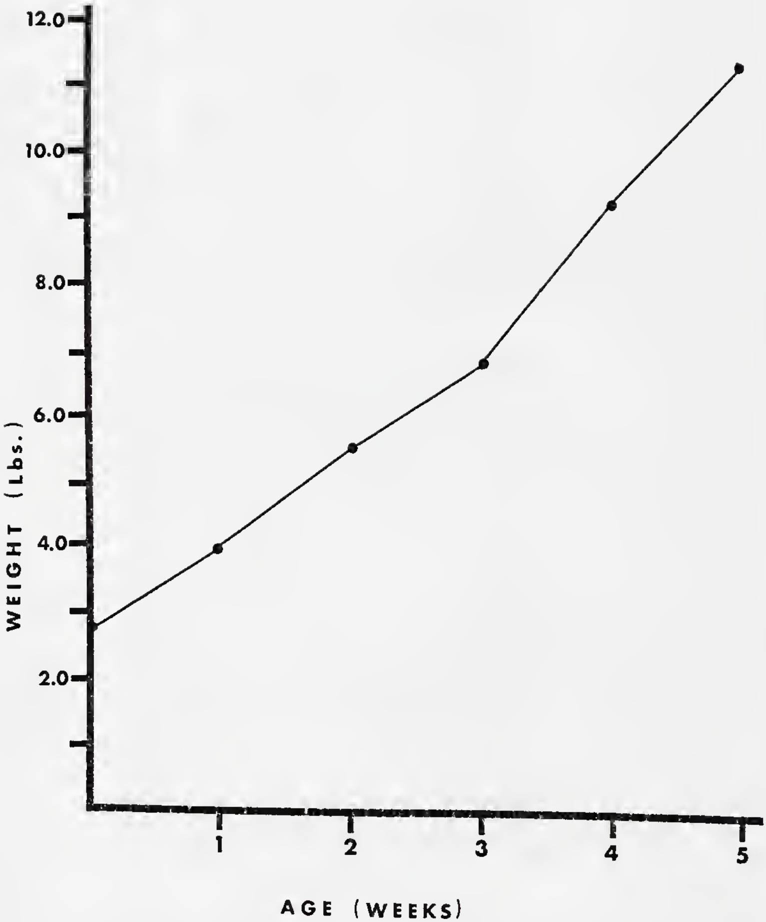

FIGURE 3. Average growth curve of pigs which survived Trial 3.

The average growth curve (Fig. 4) changed slope when the pigs were 2 weeks of age; only one pig survived which had been fed Diet C, but this pig performed better than the average.

The major cause of the very high mortality was diagnosed as Hemagglutinating Encephalomyelitis Virus (HEV) or Vomiting and Wasting disease. The disease can take 2 forms: either a severe encephalomyelitis or a chronic wasting of the pigs in which the pigs may recover but are stunted in growth and few recover sufficiently to be of economical value. The pigs in this study were apparently afflicted with the encephalomyelitic form of the HEV. The few studies done on HEV have been done primarily in Canada (Alexander and Saunders, 1969; Alexander, Richards and Roe, 1959; Roe and Alexander, 1958; Cartwright _et al._, 1969; Bruner and Gillespie, 1973).

There is a marked age incidence and it is most common and severe in pigs less than 2 weeks of age. Morbidity is variable in both relative numbers of litters in a herd and even the number of pigs affected within a litter. The mortality rate in very young litters may approach 100%. The duration of most outbreaks is brief and rarely last longer than 2 weeks; litters not affected during the first week of an outbreak, or farrowed 2-3 weeks after an outbreak begins, usually remain healthy. No recurrances have been reported in herds. Apparently antibodies against the corona virus are developed; when pigs are reared artificially the protection provided by sow's milk are no longer present, thus a high mortality can occur, as it did here. No treatment, either antibiotics or chemotherapeutic drugs have been effective.

In Trial 4, the symptoms were very similar to those reported in the literature, and varied in severity. The pigs were first noticed to be nervous and not as active as usual. Within 24 hours a few pigs were observed to vomit shortly after eating, although vomiting was never severe in any of the pigs. Pigs which had been scouring had this condition clear up for a few hours; then pigs developed a yellow, green or black watery diarrhea. The pigs rapidly lost

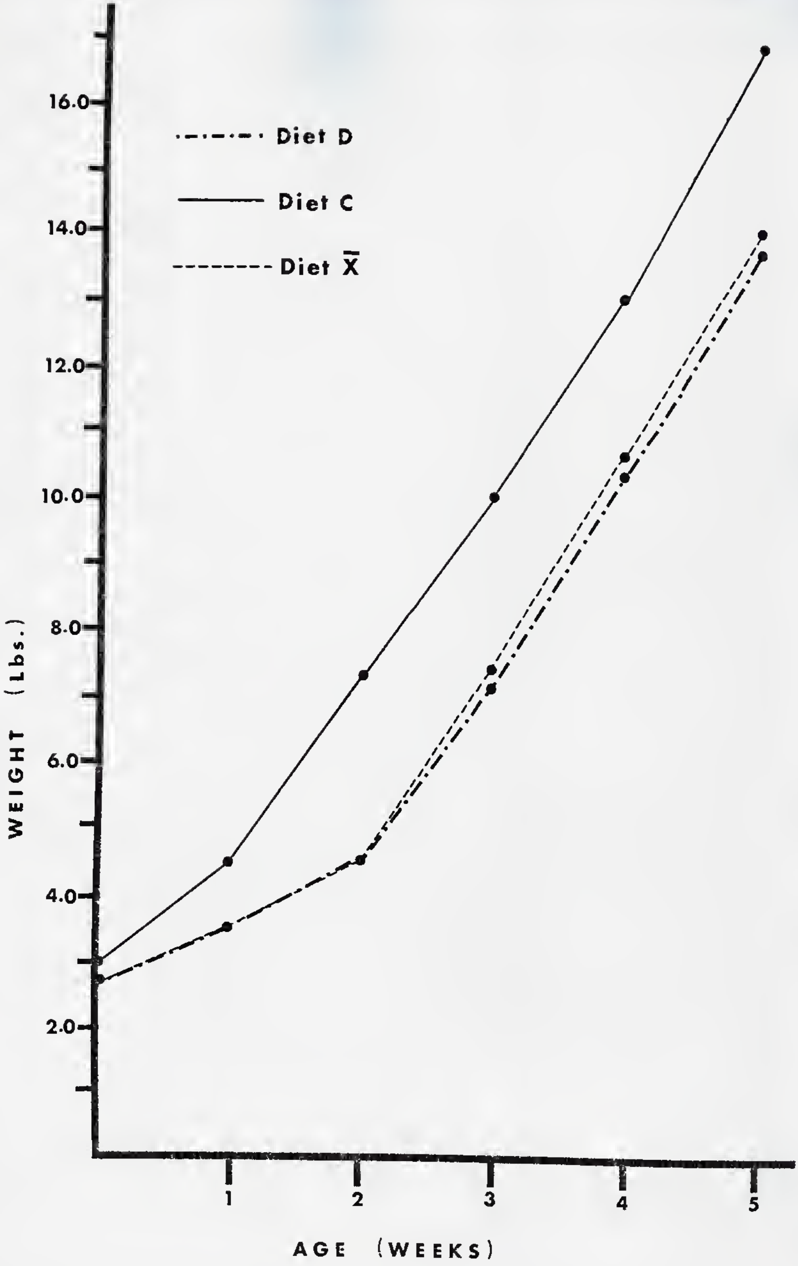

FIGURE 4. Average growth curves of pigs which survived Trial 4.

condition and became emaciated, not only from the diarrhea but also an inability to eat. In most cases reported in the literature, pigs are usually severly constipated, although in a few outbreaks a yellowish watery diarrhea has been noted (Roe and Alexander, 1958).

Many pigs were hungry and dipped their snouts in the milk replacer but were unable to swallow; they acted frustrated, stood against the feed cup, gnashed their teeth and had a bubbly salivation. The pigs often emitted a high-pitched squeal; apparently the throat muscles are paralyzed and cause the swallowing difficulties and change in voice. The pigs often stood or lay in awkward, unnatural poses, and pressed their heads against the sides of the cages. Fraser (1963) stated that head pressing is likely to be more than a special form of supporting and stabilizing behavior in an animal suffering diminished awareness, or consciousness, through depressed cerebral function. The body temperature remained normal. The abdomen became tense and appeared distended, and pigs strained to pass even watery feces. Some pigs became constipated and required an enema once daily for 1-3 days. Feces passed were usually small, hard pellets. Some pigs had subdued sneezing, coughing and rapid breathing. One pig developed an umbilical hernia.

As the disease progressed, the snouts and feet tended to become slightly cyanotic and pigs felt cold to the touch. No gross lesions were observed at necropsy, which is very typical of the disease. The first group of pigs was affected the most severely, while pigs which went on trial later and after 2 days of nursing were not so severely affected. No treatments were effective for the diarrhea. Several pigs which were unable to eat were given an interperitoneal injection of a glucose solution; the pigs rapidly became more active but usually died within a few hours. Hypoglycemic symptoms are evident when blood glucose concentration reaches approximately 50 mg/100 m., although a comatose pig with as low as 7 mg/100 ml may be completely revived within minutes of intravenous, subcutaneous or intraperitoneal glucose therapy (Goodwin, 1955; Aherne et al., 1969a).

The disease had a drastic effect upon the growth of the pigs. Initially, poor growth was probably due to the diarrhea and difficulty in eating; later, the poor rate of gain was probably due to the immobilization of the gut. White et al. (1969) reported that the growth performance of pigs with gastric stasis is poor, whether or not the pigs develop diarrhea; unthriftiness might result from failure of nutrients to pass through the gut properly. They also suggested that under such conditions, invasion of the body by normal bacteria of the gut could occur, hastening death. Recovery of the pigs which survived was rapid. Alexander et al. (1959) reported that the majority of pigs which survived the encephalomyelitic form of HEV for 3-5 days of illness recovered within 7-10 days, and recovery of some pigs showing nervous signs was remarkable for its speed and completeness.

Although diagnosed as HEV, the symptoms are also very similar to those reported for rotaviral diarrhea (Lecce, Coalson and Mock, 1972; Lecce and King, 1977). In the farrowing house there was severe diarrhea in most litters but there was not a sharp increase apparent in the mortality rate.

Trial 5: Only one pig died for a total of 4.5% mortality; the pig died at 3 days of age and 2 days after weaning. This was the small runt which had several deep cuts and appeared to have been stepped on by the sow. In none of the trials were pigs which had severe cuts able to survive more than a few days. The pig was extremely thirsty when weaned and immediately drank the Pig 95; within a few hours it appeared to have trouble swallowing. Another runt from the same litter also appeared to have trouble swallowing or lowering its head and walked in a hunched position, although it did recover within a few days. Later however, this same pig developed some swollen joints, dewclaws and toe pads. Lincomycin and Tylan seemed somewhat beneficial in relieving this condition. A large healthy pig from another litter also appeared to have some swallowing difficulties at 2-3 days of age. All 3 of these pigs were on Diet E.

One runt pig on Diet E started vomiting when 18 days of age and within 24 hours had tearing of the eyes and much exudate around them; the voice became high-pitched and the pig started scouring. The abdomen swelled and was very rigid. After 2 more days the pig started to return to normal; the symptoms greatly resembled those of the HEV which was experienced in Trial 4. This pig grew very slowly and was weaned when it weighed only 7.3# at 31 days of age.

Diarrhea was almost non-existant and 1-2 days of treatment with Gentamicin invariable cleared up the scours. Gantamicin has been shown to clear 89% of the pigs of Ecoli diarrhea within 24 hours (Ensley, 1976; O'Donovan and Ensley, 1976). Occassionally feces tended to be less firm as the amount of diet was increased but decreasing the amount of diet slightly for one feeding relieved this condition. The pigs actually tended to be constipated. One pig developed a small umbilical hernia when it was 2.5 weeks old and this may have been partly due to the great strain upon the abdomen when the pig ate large amounts of feed at one time. Another pig developed a rectal prolapse when 17 days of age. The pigs attempted to defecate immediately after eating and the additional strain upon the abdomen may have been partially responsible for these 2 pigs' problems.

All except one pig with the leg deformities survived and the tendons gradually stretched and the pigs were able to walk normally. Initially the pigs were able to move about by wedging the toes in the screened floor of the cages. All the crippled pigs were from 2 litters; it is questionable how well the pigs would have been able to grow and survive if they had remained with the sows.

The feeding level of Diet C was increased from 14.0% solids to about 28% solids when the pigs were 2.5 to 3 weeks of age; the pigs had been growing slowly even though they had been the largest pigs at birth, and the pigs acted hungry continually. No digestive upsets were encountered when the diet was modified, and the pigs ate the diet well even though it contained a much higher solids content than sow's milk, which is approximately 18-20% solids.

The growth curve of pigs fed Diet C differed greatly from that of pigs fed Diet E (Fig. 5); the overall average growth curve was most like Diet E primarily due to 13 pigs being fed this diet as compared to only 8 pigs eating Diet C. The average growth curve changed slope when the pigs were about 3 weeks of age; however, the pigs fed Diet E appeared to experience an acceleration of growth when approximately 2 weeks of age while the pigs fed Diet C had a linear growth curve.

The pigs were weaned at an average of 32.7 days of age and 12.7#. However pigs fed Diet E were weaned at an average of 31.5 days and 13.6# as compared to 34.8 days of age and 11.3# for pigs fed Diet C. The pigs on Diet E out-performed those on Diet C, even though these pigs were of lower average birth weight. Much of this is probably due to these pigs being fed at a much higher level of feeding the first 3 weeks as well as receiving a diet higher in crude protein. The performance of pigs fed Diet C, while less than that of pigs fed Diet E, was still respectable. In addition, Diet C is much less expensive. The pigs most likely would have had a much higher level of performance if the solids level had been higher at an earlier age.

Milk intake and weight gain are signigicantly correlated (Leman et al., 1972). The most important factor in weight gain of suckling pigs is feed intake or milk yeild of the sow, especially the first 3-4 weeks of life (Allen and Lasley, 1960; Barber, Braude and Mitchell, 1955; Donald, 1939) and variation in growth rates within a litter may be primarily due to differences in feed intake since mammary glands differ in the amount of milk produced (Donald, 1937b). Bayley and Holmes (1972) reported that the growth of early weaned pigs followed feed intake, and Scoot, Owen and Agar (1972) reported more rapid growth rates with increased maximum daily milk replacer intakes. Braude et al. (1970a) also reported greater gains with 20.0% solids than 12.5% solids in the diet. England, Chapman and Bertun (1961) reported that consumption per unit of body weight and gain per unit of body weight are positively correlated. Pond et al.

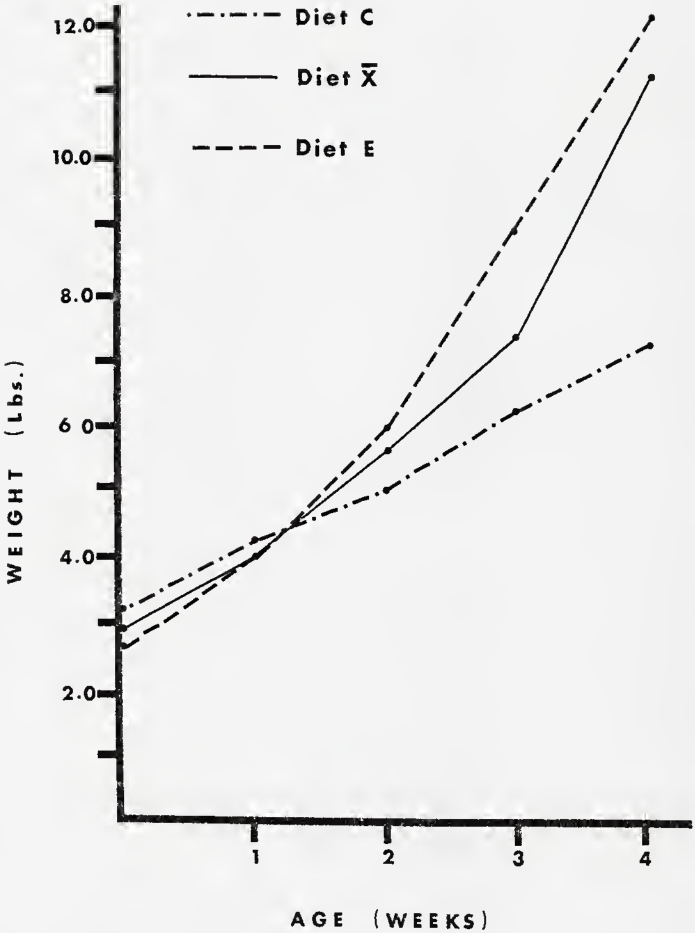

FIGURE 5. Average growth curve of pigs which survived Trial 5.

(1971c) reported an average daily gain of only 44-69 gm for pigs receiving 14% dry matter liquid diets for a 21-day period.

GENERAL OBSERVATIONS, RESULTS AND DISCUSSION

Major Problems: In the first 3 trials the major problem was in getting the pigs fed hourly. It was primarily due to the dry feed sticking to the feeding tubes and clogging them. Also, if the tubes were not perfectly aligned, the feed was not dispensed properly. There were also occassional electrical problems with the drive motor. In these first 3 trials, there was also the problem of the edema and diarrhea.

The diarrhea was probably partly due to the irregular feeding. As seen in Table 4, the poorest average daily gain and total weight gains were made by pigs in the first 3 trials. Another reason for the diarrhea may be the failure to adequately control the relative humidity and prevent temperature fluctuations. Reccommended relative humidity levels vary from 40-50% (Palmer, 1976; Sneider and Sarett, 1966a). Goodwin (1973) generalized that the relative humidity be kept between 40-60% since below 40% coughing may occur and above 60% scouring may occur. Brent (1975) noted that pigs may scour if exposed to a 10% change in relative humidity within a 30-minute period. He also reported that the maintenance of a constant temperature is as important as the actual temperature itself since variations of more than 5^{o}F can lead to scours, poor performance and even death.

With the pigs exhibiting the severe edema in the first 3 trials, it was initially suggested that perhaps it was an iron deficiency. However, anemia usually results in just edema of the head and neck area, and all pigs had received an iron injection as well as ingesting iron in the milk replacer. It was also suggested that the pigs had developed an allergy. Anaphylactic shock results from both active and passive sensitization (Hoerlein, 1957); Riis and Jakobsen (1969) report that it is important that within a few days the intestinal epithelium becomes impassable for proteins and large peptides since the absorption of protein or other antigenic compounds by an animal capable of antibody formation may cause allergy and anaphylactic shock. Thus it seemed possible the pigs could develop an allergy to the feed since the baby pigs are capable of antibody formation and the gut absorbs macromolecules for several days. However, since several pigs did recover, it is unlikely that the pigs had developed an allergy. In Trial 3 the edema seemed to be litter-related, although not in the other 2 trials.

Lecce, Morgan and Matrone (1962) fed an amino acid milk to pigs and at 2 weeks they had made very poor weight gains, were extremely edematous and unable to use their limbs. It was also possible that the edema was due to a calorie-protein imbalence. Pigs fed a low protein-low fat diet develop a condition similar to marasmus in humans (Pond et al., 1965); the addition of extra calories, such as fat or carbohydrates, to a low protein diet has resulted in biochemical and anatomical changes in piglets resembling kwashiorkor in human infants (Pond et al., 1965, 1966).

Body and organ development is partially regulated by the absolute protein and caloric intake as well as dietary protein:calorie interactions (Badger et al., 1972). The protein requirement varies with the caloric density of the diet (Manners and McCrea, 1963a; Jones, 1969; Menge and Frobish, 1976b) and as the fat level in the diet is increased the protein level required also increases (Jones, 1969; Lecce and Coalson, 1973). In addition, protein quality also becomes more critical at high energy intakes (Jones, 1969; Lowrey et al., 1962). Sherry et al. (1978b) reported that average daily gain and gain/feed ratios are highest with a wide protein:calorie ratio; Manners and McCrea (1963a) reported that the protein:energy ratio optimum was always wider in milk replacers than in sow milk and much less protein is required with sow milk to support optimum performance than with the milk replacers. They theorized that it is possible the amino acid composition of sow milk is superior than the milk replacer protein, or that the less frequent feeding with artificial diets may be partially to blame.

Numerous reports of scours, poor performance and even death when low protein-high calorie diets are fed (Lecce and Coalson, 1973, 1976; Pond et al., 1966; Diaz et al., 1959; Barnes et al., 1966; Coalson and Lecce, 1972) can be found in the literature. James (1971) made a comprehensive review of the effects of protein-calorie malnutrition. He concluded that malnutrition is often associated with diarrhea, which is caused at least in part by the malabsorption of carbohydrate. The mechanisms involved include retention of water within the intestine as unabsorbed carbohydrates accumulate, and this results in an increased rate of fluid passage down the intestines. In addition, bacterial fermentation of the undigested carbohydrates in the lower bowel aggravate the diarrhea. The intestinal wall becomes thin and damaged and results in malabsorption of carbohydrates, fat, protein and other nutrients, and severe mucosal atrophy is a specific effect of protein depletion.

Symptoms vary according to the severity of the protein-calorie imbalence (Pond et al., 1966). The severity of symptoms is inversely related to the absolute amounts the pigs consume daily (Lowrey et al., 1962); both caloric density and protein quality exert an effect on the severity of symptoms (Lowrey et al., 1962) as well as the weight of the pig, with smaller pigs having more mortality and severe symptoms (Pond et al., 1966).

Symptoms include anemia, lower serum protein and serum albumin, subcutaneous edema, apathy, feebleness, and emaciation (Pond et al., 1966; Lowrey et al., 1962). There may also be edema of the heart, skeletal muscles, lungs, brain and kidney glomerulus.

The milk replacer fed in these first 3 trials had a crude protein content of approximately 20.0%, which is low for baby pigs. In addition, Woodham (Cuthbertson, 1969) states that dried milk powder is particularly susceptable to storage deterioration, and the duration and conditions of storage have deleterious effects upon protein quality. Several bags of the milk replacer looked as if there could have possibly been conditions under which the milk replacer milk protein could have been adversely affected, which would have lowered the protein value of the feed even lower than 20.0%. This, in combination with the high fat level of the diet (15.0%), could have led to a protein-calorie imbalence. Cheeke and Stangel (1972) reported that heating lactose-containing diets markedly reduced the nutritive value for growing rats and supplementation with lysine overcame this effect; apparently a Maillard or Browning reaction occurred in which the aldehyde group of the reducing sugar lactose reacted with the epsilon amino group of lysine, resulting in the formation of complex brown polymers and rendering lysine unavailable for absorption. The addition of dried skim milk to increase the protein content and lower the fat content of the diet in the second and third trials had no effect on the edema, although better gains were made by the pigs.

In Trial 4, the effects of HEV upon weight gain and average daily gain are obvious. However, the pigs which survived made remarkably fast recoveries and had weights nearly equal to the average of the pigs in Trial 5 which seemed to have no health problems. The majority of pigs in Trial 4 were fed hourly SAM meal and supplemented 3 times daily with Pig 45 and Pig 95. There was little problem with the SAM meal sticking to the feeding tubes and the pigs were usually kept on a regular feeding schedule.

Appearance: The appearance of the artificially reared pigs was always poorer than sow-reared pigs, although the pigs in Trial 5 nearly matched the sleek, glossy appearance of healthy, conventionally reared pigs. Brent (1975) remarked that artificially reared pigs look different from sow-reared pigs and it takes experience to judge the exact condition of the pigs. Several researchers have mentioned the rough hair-coats, lack of glossy sheen and mild dermatitis (Berry et al., 1962; Eggert et al., 1954); Weybrew et al. (1949) reported that the mild dermatitis seemed litter-related, cleared after 2 weeks and by 8 weeks of age all the pigs had glossy coats.

Pigs fed Diets A and B, and occassionally those fed Diets C and D, all had a sticky brown exudate below the nasal canthus; in Trial 5, this exudate occurred with only one pig and was not profuse. Many other researchers have noted this exudate (Bustad and Cunha, 1947; Bustad, Ham and Cunha, 1948; Johnson, James and Krider, 1948; Weybrew _et al_., 1949); the condition was noted when very poor diets were fed (Pettigrew and Harmon, 1977; McRoberts and Hogan, 1944) and Lehrer, Wiese and Moore (1952) commented that it may sometimes be associated with most water-soluble vitamin deficiencies.

Behavior: Generally when the pigs were first weaned from the sow and placed in individual cages, the pigs were very excited and upset; they paced, squealed and climbed the bars of the cages, and it appeared they wanted to be with other pigs. Usually the pigs had settled down within a few hours and most had eaten at least some of the liquid diets. The pigs generally ignored the feed when first put in the cages except for several very small runts which immediately ate the feed, especially the electrolyte solutions; some of these small pigs had been observed drinking from the sows' drinking bowls. Although Johnson, James and Krider (1948) pushed the pigs' snouts into the pans to train them to eat, most researchers report that the baby pigs quickly adapt to the new environment and learn to eat from pans within a few hours (Haelterman, 1956; Drees and Waxler, 1970a; Braude _et al_., 1970a; Kohler and Bohl, 1966b; Palmer, 1976; Weybrew _et al_., 1949).

It was often beneficial to simulate the sounds of suckling and a sow calling her pigs to nurse; this often resulted in a reluctant pig being persuaded to eat. McBride (1963) also observed that pigs seemed to be attracted to sounds made by the sow, and although the grunts are difficult to describe they are easily identified; they also noted that sounds made by pigs at the udder may attract the remainder of the litter before the sow calls, but the sow's call was a much more effective signal, and sleeping pigs can be awakened by the imitation of suckling sounds. Stone, Brown and Waring (1974) observed that cyclic playback of recorded feeding sounds shortened the interval between nursings, the sows and pigs showed more response from birth to 3 weeks than 3-5 weeks, and milk production of sows and weaning weight of litters were significantly increased.

The pigs would usually pair off and sleep side by side with a pig in an adjacent cage. Some pigs would sleep so soundly that they could be picked up and handled without awakening. Occassionally one would be observed having the same nose- and leg-twitching often observed in sleeping dogs.

The pigs could occassionally be observed making rooting motions and when provided with a towel they would bunch it up onto a nest. However, older pigs generally rejected the towel and rooted it out of the cage and into the feed cups. Many pigs would 'steal' a neighbor's towel by pulling it into its cage and urinating on it; usually all pigs would immediately urinate on the clean towels, perhaps as a way of identification.

When several days old and feeling healthy, the pigs would often play with other, especially by racing back and forth, snout to snout. Occassionally this would result in sprained legs as maneuvering in the small cages became difficult. The pigs also enjoyed playing with small objects such as small plastic cups.

The pigs usually selected one corner at the rear of the cages to dung in, and often turned sideways so as to dung into the neighbor's cage. Occassionally a gilt would develop the habit of urinating in her feed cup; if the pig was caught in the act a few times and poked, they could usually be trained not to do this.

The pigs were very possessive of their feed cups; they often slept with their heads or even entire bodies in the cups, which was also observed by Palmer (1976). When washing the cups, several pigs would come up, stick their snouts into the cups, squeal and try to shove the hand out of the cup although they never actually tried to bite. Palmer (Johnston, 1974b) often found it helpful to put a new pig in a cage next to one that had been in the unit for several days so that the new pig would learn to eat more quickly; on the sow, competition from another pig will usually stimulate a pig to defend a teat (McBride, 1963). When fed, the pigs would assume a defensive posture and block the cup from a neighboring pig since the adjacent pig, if not yet fed or if done eating, would attempt to get the next pig's feed. It often seemed that runts were much more possessive of their cups and mor aggressive when trying to get another pig's feed, as well as more defensive of their meals.

When fed by the machine, pigs rapidly learned to associate it with feed. When the machine was 2-3 cages away the pig would become restless and often start to squeal. The pigs learned to recognize in which direction the machine moved when it dispensed feed to their row. If the machine was broken and passed the pig without feeding it, the pig would become quite upset, squeal and pace. Some pigs appeared to 'beg' the machine by sticking their tongue out and cupping it as if wrapped around a teat, and wiggle it at the feeding tube until it dispensed feed. Others intently stared at or poked the tube. In between meals the pigs would often much time rubbing the feed cups with their snouts, much as pigs on the sow spend time massaging the udder.

When fed by hand or when the machine was broken the pigs associate the researcher with feed. A feeding order was especially important since the pigs rapidly learned when it was their turn to be fed, and if the routine was varied the pigs became upset. One pig squealing and signaling that it was feeding time generally aroused all the pigs. The pigs also associated each of the 3 cups with a particular feed and were confused if the order was alterred.

When fed only 3 times daily the pigs could consume large quantities at one time. If feed was still in the cup when a pig could ingest no more, it would squeal and dip the snout in the feed; after several minutes the pig would go to the rear of the cage and fall asleep. They would generally wake up after 45 minutes and finish the meal.

Menge and Frobish (1975, 1976a) observed considerable differences in behavior, feeding patterns and learning amoung pigs. Lewis et al. (1955) observed variation in the length of time before baby pigs started to eat dry diets. In these 5 trials the pigs would usually push the dry creep feed out of the cups and refuse to eat it as long as they were also fed liquid diets. Even if the volume of liquid diet fed was decreased, pigs would often go hungry rather than eat dry feed. Some pigs would eat the feed if it were dampened; others would refuse to eat their own feed but if another pig's old creep feed was placed in its cup the pig would eagerly consume it. The SAM pellets were eaten slightly better than the dry creep feed; one pig learned to take mouthsful of water, spit it on the SAM pellets and dissolve them.

Body contact seemed important to many pigs. Several liked to be scratched and others, when small, liked to be held and stroked. Some pigs would wiggle the doors of their cages until they got their daily scratch. Schoen et al. (1974) handled baby pigs by cradling it in the right arm and stroking with the left hand 1 minute per day; they reported that for the sow-reared pigs the reaction to handling for 4 weeks was variable within and amoung pigs. They reported that the pre-weaning handling did not affect weight gain before or after weaning and did not affect mortality between birth and 8 weeks of age.

The pigs were very secure in their cages and were reluctant, especially when older, to leave the cages. If put into a strange cage they would be restless for several hours. The pigs were able to distinguish the caretaker from strangers in the room and would become much more subdued when a stranger was in the room.

Weaning: When the pigs were weaned into the elevated floor pen they were very nervous and had to adjust to a new type of floor and associating directly with other pigs. They were able to recognize the pigs which had been in adjacent and often paired off with them for sleeping and eating activities. A pan of dampened creep feed was usually not eaten any better than dry creep feed. Pigs still recognized the person who fed them and for several days would run up to that person and squeal for feed. Even when moved to the nursery the pigs recognized their "substitute mother" and for several weeks would come up to be scratched.

The first 2-3 days there was little fighting; the social order these first few days generally seemed to be decided by weight, with pigs climbing on top of each other. Ewbank and Meese (1972) reported that pigs sort out a social order based on dominance hierarchy the first 24-36 hours after weaning, and 4-5 days later had developed a group identity, and even pigs low in social rank readily attacked strangers. This meant that the pigs which had been reared artificially had to be weaned in batches so that they were not put into a group of pigs which had established an identity. Pigs which had been reared artificially did not seem to be at any great disadvantage if they were simultaneously weaned with a group of sow-reared pigs of similar size. Scheel, Graves and Sherritt (1977) reported that dominance rank within litters after weaning is based primarily on previous relationships while dominance rank amoung litters after weaning is based mostly on weight than previous experience. Weybrew et al. (1949) reported that when artificially reared pigs were weaned with sow-reared pigs the artificially reared pigs soon lost any weight advantage and could not meet the competition, and apparently were unprepared physiologically to handle the coarse natural feeds. The pigs in these 5 trials had been consuming some creep feed prior to weaning and seemed to be able to cope with being weaned with sow-reared pigs if they were of similar size. Catron et al. (1949) also reported satisfactory post-weaning performance with artificially reared pigs.

The pigs were weaned primarily on a weight basis. Some researchers wean all pigs at a set age or weight. Weybrew et al. (1947) artificially reared pigs to 8 weeks of age; however since the labor requirements can be high, and the feeds expensive, it is desirable to wean the pigs to dry diets socner. Zamora, Schmidt and Veum (1975) and Danielson (1968) weaned pigs at 21 days of age, Lee, Kauffman and Grummer (1973) weaned at 28 days of age and Scoot. Owen and Agar (1972) weaned at 7 kg. Lodge (1969) concluded that individual weight is important through its influence on the age at which pigs can be weaned, and the 3 major determanents of weight for age in pigs are birth weight, milk consumption and consumption of supplemental feed, and the relative importance of each factor varies with each pig although the effect of birth weight decreases and feed consumption increases with age.

Survival: The % mortality ranged from 4.5% to 56.0% (Table 4) with an overall 35.3% of the pigs dying. In Trials 1 and 3 the mortality was about what would have been expected if the pigs had been left with the sow; in Trials 2 and 4 the mortality was much higher than the average mortality of sow-reared pigs while in Trial 5 the mortality was much lower than with sow-reared pigs. Mortality rates for artificially reared pigs reported in the literature vary widely, and some researchers do not include any pigs which die within 24 hours. Many factors affect the mortality rate, including amount and quality of colostrum ingested, age, weight, diet composition, feeding regimen and farrowing conditions. In Table 1 it can be seen that while a large proportion of the deaths may be attributed to HEV, the majority of deaths occurred amoung sick, injured or undersized pigs.

Survival rates often vary from trial to trial within one experiment; Johnston (1974b) reported ranges of 76-97%, Coalson, Maxwell and Hillier (1971) had a range of 83-100%, as did Coalson et al. (1973). Survival rates reported range from 0% in early studies in which sucrose was included in the diets (McRoberts and Hogan, 1944), to 76.3% (Anon., 1973a), 80% (Palmer, 1976), 87.5% (Weybrew et al., 1947, 1949), 89-92% (Pettigrew and Harmon, 1975; Menge and Frobish, 1976a; Jurgens, 1974; Johnston, 1974b; Coalson, Maxwell and Hillier, 1971; Coalson et al., 1973), 95.6-97% (Anon., 1973b; Catron et al., 1949; Menge and

Frobish, 1976a; Young, Underdahl and Hinz, 1955), 99.6-100% (Kornegay and Blaha, 1957b; Grummer, 1954; Danielson, 1968; Clark, 1978). Pigs reared under sterile conditions have reported survival rates of 79% (Wolfe et al., 1975) and 82,3% (Danielson et al., 1976). Stanton and Mueller (1977) considered an average survival rate of 90% to be satisfactory. Blaha and Kornegay (1975) reported a survival rate of 73% if the pigs were fed 3 times daily as compared to 91% if the pigs were fed 16 times daily. Pettigrew et al. (1977) reported a higher survival rate for piglets fed ad lib. rather than limited fed. Danielson et al. (1976) reported some artificially reared litters sufferred extreme death losses while other litters experienced normal survival rates.

Birth weight was negatively associated with the % mortality (Table 2) and the coefficient of correlation of birth weight group and %survival was 0.9638. A negative correlation of birth weight and mortality is often reported in the literature (Pettigrew, Zimmerman and Ewan, 1971; Anon., 1973a; Scheel et al., 1977; England, Eay and Fogg, 1976; McBride et al., 1964; Pomeroy, 1960b; English and Smith, 1975; Fahmy and Bernard, 1971; Lodge et al., 1961; Hartsock and Graves, 1970, 1976; Bustad et al., 1948; Bille et al., 1974a; Bereskin et al., 1973; DeRoth and Downie, 1976).

Averaged over the 5 trials, the pigs which weighed less than 2.0# at birth had 35.3% survival when artificially reared as compared to only 17-18% chance of survival when sow-reared (English and Smith, 1975; Pomeroy, 1960b); pigs weighing less than 2.5# at birth had a 50% chance of survival and an 85.4% chance if they weighed more than 2.5#, as compared to figures of 44.0% and 85.0%, respectably, reported in the literature for sow-reared pigs (Stanton and Mueller, 1977; Freeden and Pland, 1963). However, Fahmy and Bernard (1971) reported pre-weaning mortality rates of 49.83, 13.33, 8.32, 5.40 and 2.94% for pigs in birth weight ranges of pigs in similar birth weight groups as the pigs in these 5 trials with mortality rates of 64.7, 35.3, 17.0, 13.0 and 0.0%. Palmer (Johnston, 1974b) stated that they had difficulty saving pigs weighing less

TABLE 1. Major causes of death.

Major factor attributed to be cause of death	Number of pigs	% of dead pigs
Edema	4	9.8
Diarrhea	4	9.8
HEV	10	24.4
Salmonella, E. coli or Streptococci	2	4.9
Poor pig[a]	20	48.8
Unknown	1	2.4

[a]Ill when weaned from sow, runt and/or injured.

TABLE 2. Mortality rates and time of death for different birth weight groups.

Birth weight group	Birth weight range (lbs.)	% of total number of pigs	% mortality	Age at death (days)	Time of death after weaned from sow (days)
1	≤ 2.0	29.3	64.7	8.5	6.6
2	2.1 - 2.5	29.3	35.3	8.7	7.7
3	2.6 - 3.0	18.1	19.0	6.3	4.4
4	3.1 - 3.5	19.8	13.0	8.8	5.2
5	≥ 3.6	3.5	0.0	-	-
$\bar{x}$	-	100.0	35.3	8.3	6.5

than 2.0# but could save 90% of those pigs weighing more than 2.0#. Clark (1978) reported that runts survive as well as larger pigs if they receive adequate colostrum and do not have to compete with larger pigs; Donald (1937a) noted that weak pigs respond rapidly to preferential treatment. In these 5 trials, in general, the runts made great efforts and continued to eat as long as they were able. Also, there was a 41.5% increase in survival as the birth weight rose above 2.0# with over half the increase occurring between 2.0-2.5#. Anon. (1972) reported that as birth weight rose above 2.0# there was a 40% increase in survival rate with over half of this increase occurring between 2.0-2.4#.

As can be seen in Table 3 the earlier the pigs were weaned the greater the mortality except in pigs weaned when older than 2 days; this is due to these older pigs generally being sick or extremely slow-growing when weaned from the sows. The age the pigs died varied greatly in each trial (Table 4) but the average age was 8.3 days and 6.6 days after weaned from the sows. However, in Table 2 it can be seen that all birth weight groups tend to die at the same age except pigs in birth weight group #3.

TABLE 3. Age at weaning in relation to mortality.

Age weaned from sow (days)	Total number of pigs	Number of pigs which die	% of pigs which died	% mortality
0.5	36	16	39.0	44.4
1.0	34	11	26.8	32.4
2.0	21	5	12.2	23.8
> 2.0	24	9	22.0	37.5

Of the 41 pigs which died, 25% had lost weight between the time they were born and when weaned from the sow, while only 17.3% of the pigs which survived

Table 4. Mortality and performance of pigs in different trials.

	TRIAL 1	2	3	4	5	x̄
Number of pigs						
survivors	13	11	14	16	21	75
died	5	14	4	17	1	41
total	18	25	18	33	22	116
% mortality	27.8	56.0	22.2	51.5	4.5	35.3
Age of death, days	3.3	9.4	8.1	8.4	3.0	8.0
Age wean from sow, days						
survivors	2.4	3.2	1.3	1.6	0.9	1.8
died	0.7	1.3	1.1	2.4	1.0	1.4
average	1.9	2.2	1.3	2.0	0.9	1.7
Average number of days after weaned from sow	3.3	9.4	8.1	8.4	3.0	8.0
Average number of days fed liquid diet	25.4	37.0	34.8	35.2	31.8	32.7
Average weight, lbs.						
Birth						
survivors	2.4	2.7	2.7	2.7	2.9	2.7
died	1.5	2.2	2.3	2.1	1.4	1.9
average	2.2	2.4	2.6	2.4	2.8	2.4
Weaned from sow						
survivors	2.5	2.8	2.6	2.9	3.0	2.8
died	1.5	2.1	2.4	2.1	1.3	1.9
average	2.2	2.4	2.5	2.5	2.9	2.5
7 days of age	3.5	3.8	3.9	3.4	4.1	3.7
14 days of age	4.4	4.8	5.5	4.7	5.7	5.0
21 days of age	5.7	5.8	6.7	7.3	7.4	6.6
28 days of age	7.1	8.2	9.3	10.5	11.1	9.2
Weaned from liquid diet	6.8	13.2	12.1	15.2	12.7	12.2
Gained during liquid feeding period	4.4	10.4	8.5	12.3	9.7	9.2
Average daily gain, lbs.						
0-7 days of age	0.15	0.15	0.17	0.10	0.17	0.15
0-14 days of age	0.14	0.15	0.20	0.14	0.20	0.17
0-21 days of age	0.16	0.16	0.19	0.22	0.23	0.19
0-28 days of age	0.17	0.20	0.24	0.28	0.29	0.24
On liquid diet	0.17	0.28	0.24	0.35	0.31	0.28
Average weight gain, lbs.						
0-7 days of age	1.1	1.1	1.2	0.7	1.2	1.1
0-14 days of age	2.0	2.1	2.8	2.0	3.8	2.5
0-21 days of age	3.3	3.3	4.1	4.7	5.9	4.3
0-28 days of age	4.7	5.6	6.7	7.9	9.2	6.8

had lost weight (Table 5). From Table 4 it can be seen that pigs which survive were heavier at birth and gained weight before weaned from the sow while pigs which died were lighter and did not gain weight before weaned from the sow although they were weaned at about the same age. England, Day and Fogg (1976) also reported 89.0% of all surviving pigs were heavier at 72 hours of age than at birth. Surviving pigs which had lost weight averaged a weight loss of 0.3# at 2.5 days of age and pigs which died after losing weight before weaned from the sow had an average weight loss of 0.3# at 3.2 days of age (Table 5).

TABLE 5. Comparison of weights of pigs which survived weight loss prior to weaning from the sow to those pigs which died and had lost weight prior to being weaned from the sow.

	Survive				Die					
Birth weight group	No.	%	$\bar{x}$ weight loss (lbs.)	$\bar{x}$ age wean (days)	No.	%	$\bar{x}$ weight loss (lbs.)	$\bar{x}$ age wean (days)	% which had lost weight	% survive weight loss
1	5	38.4	0.2	4.0	9	81.8	0.2	2.4	58.4	35.7
2	2	15.4	0.4	2.0	1	9.1	0.3	3.0	12.5	66.7
3	2	15.4	0.4	4.0	0	0.0	-	-	8.3	100.0
4	4	30.8	0.2	2.0	1	9.1	0.8	0.0	20.8	80.0
5	0	0.0	-	-	0	0.0	-	-	0.0	-
$\bar{x}$	13	100.0	0.3	0.3	11	100.0	0.3	3.2	100.0	-

As seen in Table 6, 81% of the pigs weaned at 12 hours of age had not gained any weight and the 14.3% of the pigs which did gain weight only gained 0.1#; if the pigs were weaned at 1 day of age, 30.5% still had not gained any weight but 56.5% of the pigs had gained up to 0.3#. Of the pigs weaned at 2 days of age, 25% had not gained any weight since birth, but 56.4% had gained as much as 0.7#; pigs weaned at more than 2 days of age were generally sick or runts and this is reflected in the poor weight gains. These trends in weight gains agree closely with those reported in literature. Anderson and Wahlstrom

TABLE 6. Performance of pigs prior to being weaned from the sows.

Age weaned from sow (days)	% OF PIGS AT THAT AGE WITH WEIGHT LOSS OR WEIGHT GAIN												
	-0.5	-0.4	-0.3	-0.2	-0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7
0.5	-	-	-	-	4.6	81.0	14.3	-	-	-	-	-	-
1.0	4.3	-	4.3	-	4.3	30.5	17.4	13.1	26.1	-	-	-	-
2.0	-	6.2	6.2	6.2	-	25.0	12.6	6.2	-	18.8	-	6.2	12.6
>2.0	7.7	7.7	7.7	-	7.7	7.7	38.4	7.7	-	7.7	7.7	-	-

(1970) report that pigs gain practically no weight the first 18 hours although Bille, Larsen and Nielsen (1972) noted that the weight at 2 day of age is not necessarily identical with birth weight. Braude et al. (1947) report that pigs gain only about 60 gm the first 24 hours, 135 gm by 2 days of age and 155 gm by 3 days of age; they also report that 76% of the pigs gain weight between 24-48 hours and 92% gain weight from 48-72 hours of age.

Growth: The growth curves in each trial are not linear except for pigs fed Diet C in Trial 5. In Trial 1 there was an acceleration of growth when the pigs were about 4 weeks of age; in Trials 2 and 3 the slope changed when the pigs were about 3 weeks of age and in Trial 4 this change occurred when the pigs were approximately 2 weeks of age. In Trial 5, the growth curve of pigs fed Diet C was almost linear as compared to the curve of pigs fed Diet E which changed slope when the pigs were about 2 weeks of age, and the average growth curve of all the pigs in Trial 5 changed slope at approximately 3 weeks of age. The growth curves of pigs in experiments conducted by Manners and McCrea (1963a) also are not linear and change slope between 2-3 weeks of age. Whatley and Quaife (1937) observed preweaning growth to 10 weeks of age and reported that it was curvilinear and preweaning growth could be divided into 2 distinct growth phases. They reported that growth before and after approximately 6 weeks of age was essentially linear, and the change in growth may be due to implementation of supplementary feed at about 6 weeks. Ahlschwede and Robison (1965) reported that growth to 7 weeks of age was significantly curvilinear although for the first 4 weeks the growth was nearly linear and after this time growth rapidly accelerated. In the normal growth curve for swine reported by Ittner and Hughes (1938) the preweaning growth curve appears linear. In these 5 trials the change in the slope of the growth curves does not appear to be due to any increased consumption of creep feed, but rather may reflect when the pigs became most adjusted to artificial diets; Menge and Frobish (1976a) reported that with artificially reared pigs the pigs made the slowest gains during the first period while adjusting to the new feed and environment, and made the greatest gains during the fourth period.

Anderson and Hogan (1947) reported that pigs artificially reared for 8 weeks were subject to diarrhea at first and grew at a moderate rate, but during the last 4 weeks the pigs grew at a tremendous rate. Piglets grow slowly while scouring, even if the diarrhea is mild (Anderson and Hogan, 1947; Barnum, 1971; Campbell, Brough and Fell, 1971; Cunningham and Brisson, 1957c; Menge and Frobish, 1976a). Looking at Table 7 and the growth curves, it can be seen that in general the pigs also gain slowly at first then the average daily gain dramatically increases at 2-3 weeks of age. Part of the reason for the initial slow growth may be due to the fact that when pigs are weaned early there is usually a growth check period, although it is not usually prolonged or severe (Bayley and Carlson, 1970; Elsley, 1963a; Hutchinson _et al_., 1957b; Lucas, Calder and smith, 1959b; Meade _et al_., 1964; Smith and Lucas, 1957a,c; Zimmerman, 1977). The growth check period lasts approximately 7-10 days (Lucas, Calder and Smith, 1959b; Lodge, 1969; Hutchinson _et al_., 1957b; Meade _et al_., 1964; Smith and Lucas 1957a) although the lighter or younger the pigs are weaned the longer the growth check will last (Zimmerman, 1977). Smith and Lucas (1957a) observed a significant variation in the length of the check period between litters. Growth after the check period is rapid (Smith and Lucas, 1957a,b,c) and after 2-4 weeks the weight differences resulting from age at weaning is no longer present (Zimmerman, 1977).

As demonstrated in Figure 6 and Table 8, the small pigs gain weight at a faster rate, percentage-wise, than larger pigs. There is a high correlation coefficient between age and % change in birth weight for all birth weight groups (Table 8). In Figure 6 it appears that birth weight groups 1 and 2 perform similarly while birth weight groups 3, 4 and 5 perform more nearly alike. Lodge (1969) stated that it is not known if the difference in relative growth

TABLE 7. Average daily gain (lb.) of pigs in different birth weight groups in each trial.

	Age Period (days)																							
	0 - 7						7 - 14						14 - 21						21 - 28					
Birth weight group / Trial	1	2	3	4	5	$\bar{x}$	1	2	3	4	5	$\bar{x}$	1	2	3	4	5	$\bar{x}$	1	2	3	4	5	$\bar{x}$
1	.13	.14	.19	-	-	.15	.11	.17	.10	-	-	.13	.18	.20	.18	-	-	.19	.18	.19	.22	-	-	.20
2	.00	.14	.17	.20	-	.15	.11	.28	.10	.08	-	.15	.10	.14	.30	.26	-	.17	.33	.38	.31	.34	-	.33
3	.21	.16	.13	.14	.27	.17	.20	.22	.17	.25	.24	.28	.14	.15	.21	.19	.37	.18	.37	.24	.21	.41	.84	.37
4	.10	.09	.12	.10	-	.10	.20	.16	.20	.17	-	.18	.24	.42	.39	.41	-	.38	.41	.43	.54	.46	-	.46
5 $\bar{x}$	.14	.19	.18	.19	.08	.17	.19	.25	.20	.26	.14	.22	.26	.33	.25	.39	.21	.31	.38	.50	.47	.50	.41	.47
Diet C	-	.20	.15	.13	.08	.12	-	.08	.10	.12	.14	.12	-	.20	.13	.19	.21	.19	-	.39	.42	.39	.41	.40
Diet E	.14	.19	.22	.22	-	.18	.19	.24	.31	.33	-	.28	.26	.36	.37	.48	-	.37	.38	.52	.52	.55	-	.50
$\bar{x}$ Weekly	.12	.14	.16	.16	.18	.15	.16	.22	.16	.19	.19	.18	.18	.25	.27	.31	.29	.25	.33	.35	.35	.43	.63	.37
Overall	.12	.14	.16	.16	.18	.15	.14	.18	.16	.17	.19	.17	.15	.20	.19	.22	.22	.19	.20	.24	.23	.27	.32	.24

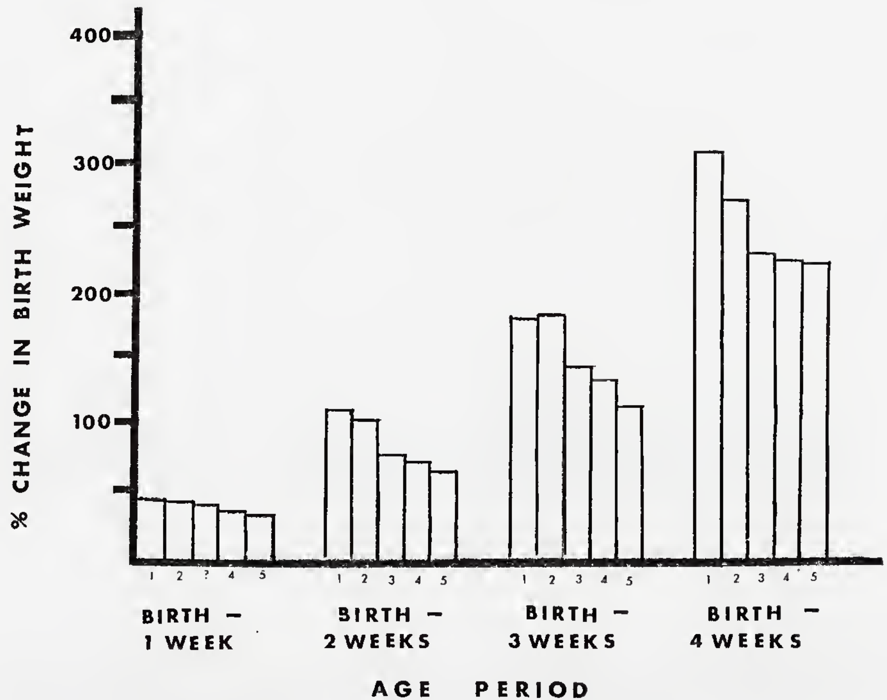

FIGURE 6. Average percent change in weight from birth by birth weight group.

rate is due to insufficient diet for larger pigs or reduced growth potential in relation to weight with increasing size. Pigs of low birth weight apparently have the capacity to ingest more milk per unit body weight than larger littermates (England, Chapman and Bertun, 1961).

TABLE 8. Percent change in birth weight of pigs in different birth weight groups.

Birth weight group	% Change in Birth Weight				Coefficient of correlation of age and % change in birth weight
	Birth - 1 week	Birth - 2 weeks	Birth - 3 weeks	Birth - 4 weeks	
1	46.6	111.9	184.4	310.8	0.9867
2	41.5	104.5	186.0	275.7	0.9263
3	39.5	79.1	144.7	231.4	0.9857
4	33.5	72.1	138.1	229.0	0.9862
5	31.3	65.4	117.4	228.1	0.9575

With artificial rearing it is possible to give small pigs the growth opportunities of larger pigs. Lecce (1971) also reported that the initial weight advantage by large pigs was not, in the absence of competition, translatable into greater % gains although they do weigh more at 8 and 14 days of age. In Figure 7 and Table 9 it can be seen that large pigs at birth are always heavier, although the medium sized pigs perform nearly the same as each other, and small pigs can gain as much or more as the larger pigs within a given period. England and Keeler (1965) concluded that as a group, pigs of low birth weight are not genetically inferior in growth capacity to heavier littermated, and Smith and Lucas (1957a) reported that when pigs were weaned from sows at 10 days of age, the initial weight was not significantly related with average daily gain or feed efficiency. When pigs are separated according to size from weaning to market, small pigs remain small but grow uniformly and medium sized pigs keep up with or even surpass larger pigs and reach market weight

TRIAL	AVERAGE WEIGHT (Lbs.) by BIRTH WEIGHT GROUP																								
	AGE (DAYS)																								
	0					7					14					21					28				
	BIRTH WEIGHT GROUP					BIRTH WEIGHT GROUP					BIRTH WEIGHT GROUP					BIRTH WEIGHT GROUP					BIRTH WEIGHT GROUP				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	1.8	2.5	2.8	–	–	2.7	3.4	4.1	–	–	3.5	4.6	4.8	–	–	4.7	6.0	6.0	–	–	6.0	7.3	7.5	–	–
2	2.0	2.4	2.9	3.3	–	2.0	3.4	4.0	4.7	–	2.8	5.4	4.7	5.1	–	3.5	5.6	6.8	6.9	–	5.8	8.3	9.0	9.3	–
3	1.8	2.4	2.9	3.2	4.0	3.2	3.5	3.8	4.2	5.9	4.6	5.0	5.0	5.9	7.6	5.6	6.1	6.5	7.3	10.2	8.2	7.8	8.0	10.2	16.1
4	1.8	2.3	2.8	3.3	–	2.4	2.9	3.7	4.0	–	3.8	4.0	5.2	5.1	–	5.5	6.9	7.9	8.0	–	8.2	10.7	11 7	11.2	–
5 $\bar{x}$	1.6	2.5	2.8	3.4	3.9	2.6	3.9	4.1	4.7	4.5	3.9	5.6	5.6	6.5	5.5	5.6	7.9	7.5	9.2	7.0	8.0	11.4	10.7	12.7	9.8
5 diet c	–	2.5	2.8	3.3	3.9	–	3.9	4.1	4.2	4.5	–	4.4	5.0	5.0	5 5	–	5.8	5 9	6.4	7.0	–	8.5	8.8	9.1	9.8
5 diet e	1.6	2.5	2.7	3.4	–	2.6	3.8	4.2	5.0	–	3.9	5.8	6.3	7.3	–	5.6	8.3	9.1	10.7	–	8.0	9.7	12.5	14.5	–
$\bar{X}$	1.8	2.4	2.8	3.3	4.0	2.1	3.4	3.9	4.4	5.2	3.7	4.9	5.1	5.7	6.6	5.0	6.5	6.9	7.9	8.6	7.2	9.1	9.4	10.9	13.0

TABLE 9. Average weight of pigs in different birth weight groups at different ages.

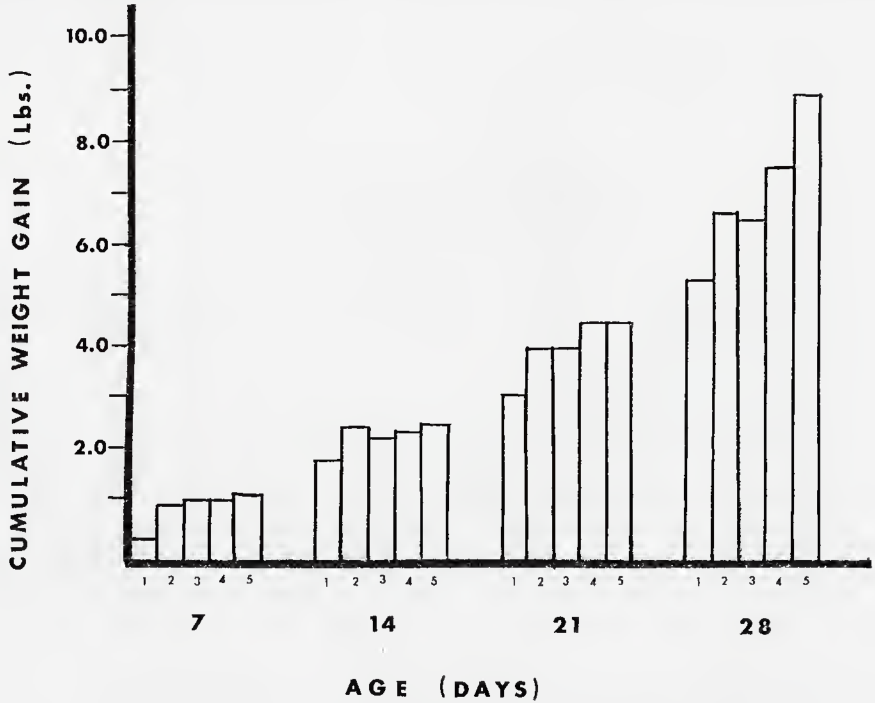

FIGURE 7. Average cumulative weight gain by birth weight group.

only 2-4 days later (small pigs reached market weight 21 days later) (Anon., 1966). Hagarty and Allen (1978) report that runt pigs require significantly longer (23 days) to reach 106 kg than control littermates, and the runts had reduced muscle growth potential.

When looking at growth from a constant weight (Table 11), larger pigs reach heavier weights at a younger age although all take the same amount of time to gain the same amount of weight, except the smallest and largest pigs. However, there were not many pigs in birth weight group #5 and several of these pigs were fed the poor diet in Trial 5; this probably had adverse effects on the growth calculations. The average age the pigs reach 10# was calculated (Table 12) and heavier birth weight pigs reach this weight soonest although medium sized pigs perform the same as each other; the difference in age at the same weights decreased as the pigs grew except with the medium sized pigs.

Although the lightest birth weight pigs have the smallest weight gain and large birth weight pigs the most weight gain, medium birth weight pigs may outgain each other (Fig. 7). However, the average weight of the pigs remains in the order of their birth weights (Table 9). Although heavier pigs were younger at certain weights (Table 11) the smallest pigs took the shortest time to gain the weight and medium weight pigs all took about the same length of time to gain the weight. In Table 12 it can be seen that the light weight pigs are narrowing the difference in time between them and the heavier birth weight pigs. England and Keeler (1965) reported that pigs of heavier birth weight required significantly fewer days to reach 6.8 kg from an initial weight of 1.81 kg than pigs of light birth weight although there was no significant difference between birth weight groups for days required to reach 11.34 kg from 4.54 or 1.81 kg. They also reported no significant difference in gain between light or moderate weight pigs for 17 days from an initial weight of 3.86 kg; they concluded that the early neonatal disadvantage for pigs of low birth weight disappears, on a

TABLE 10. Number of pigs surviving in each birth weight group in each trial.

Trial	Number of pigs which survived by birth weight group 1	2	3	4	5
1	3	5	5	-	-
2	1	3	3	3	-
3	3	4	1	5	1
4	3	3	3	7	-
5	2	6	4	6	3
Total	12	21	16	21	4

TABLE 11. Age at 2 different weights for pigs of different birth weight groups.

Birth weight group	Number of pigs	Age at 4.0# (days)	Age at 7.0# (days)	Time to gain (days)
1	12	14.7	27.1	12.4
2	21	8.9	22.4	13.5
3	16	7.5	21.3	13.8
4	21	4.4	18.2	13.8
5	4	0.0	15.4	15.4

TABLE 12. Difference in ages, at 2 different weights, between birth weight groups.

Birth weight group	$\bar{x}$ birth weight (lbs.)	$\bar{x}$ age at 10# (days)	Difference in age between groups (days)		Difference in age from Group #1 (days)	
			At birth[1]	At 10#[2]	At birth[1]	At 10#[2]
1	1.8	34.3			-	-
			5.7	4.2		
2	2.4	30.1			5.7	4.8
			2.7	0.0		
3	2.8	30.1			0.1	4.2
			3.1	4.2		
4	3.3	25.9			13.3	8.4
			4.1	2.8		
5	3.9	23.1			18.9	11.2

[1]Based on average daily gain from birth to 7 days of age.

[2]Based on overall average daily gain to 10#.

weight-constant basis, before the pigs reach 4.54 kg.

The difference in weight increases with age (Table 13) and a 1.0# difference at birth equals a 1.9# difference at 3 weeks of age. Lodge and Pratt (1963) and Winters, Cummings and Stewart (1947) report that a 1.0# difference at birth equals a difference of 1.75# at 3 weeks. However, in Table 13 it can be seen that the ratio of weight difference is the same between birth weight group #1 and all other birth weight groups except birth weight group #5.

TABLE 13. Comparison of weight at 2 different ages between birth weight group 1 and all others.

Birth weight group	Difference in weight (lbs.) Birth	3-weeks	Ratio of weight difference birth:3-weeks
1 vs. 2	0.8	1.5	0.53
3	1.0	1.9	0.53
4	1.5	2.9	0.53
5	2.2	3.6	0.61

The weekly average daily gain of pigs in different birth weight groups in each trial are listed in Table 7, and the overall average daily gain of each trial is listed in Table 4. In Table 7 the pigs in birth weight group #1 have the lowest average daily gain (ADG) while pigs in birth weight group #5 had the highest ADG except in the second week, when the pigs in group #2 had the best ADG. Pigs in birth weight groups #2 and #3 had daily gains most like the overall ADG except in the second week of life. Thus the largest pigs at birth do not necessarily always gain the fastest.

The most important factor in the growth of suckling pigs appears to be the amount of milk they consume (Braude <u>et al</u>., 1947; Donald, 1939) although birth weight is correlated with gain (Donald, 1939; Buchanan and Donald, 1937; Diaz <u>et al</u>., 1959; Pettigrew, Zimmerman and Ewan, 1971; Smith, 1971); Omtvedt et al. (1966) report that weaning weight is more of a function of gain from birth to weaning rather than a reflection of birth weight. The heritability of weaning weight is low (Ward, Rempel and Enfield, 1964) and weaning weight and litter size are negatively correlated (Fredeen and Plank, 1963; Nelson and Robison, 1976b; Omtvedt et al., 1966; Stanton and Mueller, 1977). Lodge and McDonald (1959) reported that of the total variation in 3-week weight within the litter, 39% was associated with variation in birth weight, 67% with variation in milk consumption and 80% with these 2 factors combined. They also reported that the total variation between litters was largely governed by genetic influences, climatic effects and different food values between milks.

Considerable difference of opinion as to the relation between weaning weight and age at slaughter. While some researchers report that the difference disappears with age (Fredeen and Plank, 1963; Nelson and Robison, 1976b; Severson, 1925). Menzies-Kitchin (1937) reported that under ordinary farm conditions there appeared to be definite connection between weight at 4 weeks and age at slaughter. When pigs are separated according to size from weaning until market (Anon., 1966), the medium sized pigs gained as well or faster than large pigs weaned at the same time, and the smallest pigs remained small but grew more uniformly than if they were not separated. Chapman and England (1963) reported that selection for improved post-weaning growth rate was more effective if the growth rate was estimated on a weight-constant basis than if based on age-constant or age-to-weight basis.

Menzies-Kitchin (1937) concluded that whether or not post-weaning growth rate is affected by weaning weight depended on the reason for the low weight at weaning; if it is the result of disease or some inherent weakness in the pig, the subsequent growth rate may be retarded, while if due to insufficient food, when provided with an adequate and well-balenced diet the growth should be as fast as heavier pigs but will take longer to reach market weight because they have more weight to gain. England and Keeler (1965) observed pigs with birth weights of less than 0.91 kg, 1.18-1.33 kg and more than 1.59 kg. They reported that heavier pigs required significantly fewer days to reach 6.8 kg from an initial weight of 1.18 kg than pigs of lighter birth weight, but no significant difference between birth weight groups for days required to reach 11.34 kg from 4.54 or 1.81 kg. In a second experiment they observed that light and moderate birth weight pigs did not differ significantly in weight gain in a 17-day period after they had reached 3.86 kg. They concluded that the early neonatal disadvantage for pigs of low birth weight disappears, on a weight-constant basis, before the pigs reach 4.54 kg, and as a group, pigs of low birth weight are not genetically inferior in growth capacity to heavier littermates.

In Table 4 it can be seen that the pigs in the different trials had widely different average daily gains. Trial 1 and 2 had the poorest average daily gains and the pigs in Trial 3 had a sharp decline an ADG between the second and third weeks of life, which reflects the fact that several pigs were scouring and/or suffering the effects of edema. The pigs in Trial 5 had the most consistent improvement in ADG. The general ADG improved curvilinearly, although Cornelius, Harmon and Meyer (1973) reported that with germfree pigs the ADG increases linearly over a 55 day period.

In Trial 4 the ADG was slow the first 2 weeks when the HEV outbreak occurred, then very rapid, compensatory gains were made the third week. Many researchers have demonstrated compensatory growth of pigs after restricting the the plane of nutrition, either protein or energy (Duckworth, 1965; Harrold and Johnson, 1976; Martin et al., 1974; McMeekan, 1940b; Robinson, 1964; Zimmerman and Khajaren, 1973). The immediate growth response after dietary restriciton ceased appears to be directly related to the duration of the restriction period (Robinson, 1964) and the pig may never completely recover from a severe or prolonged period (Robinson, 1964; Lister and McCance, 1967). The stage of development over which the nutritional environment is varied thus affects the nature of the response (McMeekan, 1940b) and the earlier in life it occurs the greater the effect. There are differential growth rates in the body tissues and there are differential responses of the tissues to dietary restriction (McMeekan, 1940b; Cunningham and Brisson, 1957a) with the late-developing parts being affected more (McMeekan, 1940a).

Overall, the average daily gains reported here are similar to those obtained by Scoct, Owen and Agar (1972), Palmer (1976) and Johnson, James and Krider (1948), and some what better than those of pigs in experiments conducted by Zamora, Schmidt and Veum (1975) and Cornelius, Harmon and Meyer (1973). However, the pigs grew more slowly than sow-reared pigs (Seerley et al., 1974) and more slowly than what has been reported in several other studies with artificially reared pigs (Neumann, Krider and Johnson, 1948; Kohler and Bohl, 1966b; Kornegay and Blaha, 1975b); at 14 days of age the pigs had average daily gains similar to those fed only 2% fat in studies done by Wolfe et al. (1975).

Curtis, Rogler and Martin (1969) reported weekly weight gains of sow-reared pigs to be 1.1, 1.4, 1.7 and 1.9# for the first 4 weeks of life; in these 5 trials the corresponding gains every week were 1.1, 1.4, 1.8 and 2.5#. The cumulative weekly gains of the pigs were 1.1, 2.5, 4.3 and 6.8# (Table 4). The weight gains of birth weight groups #4 and 5 seemed similar as did those of birth weight groups #2 and 3 at 21 and 28 days of age (Fig. 7). These are poorer than what is sometimes reported in the literature. Anon. (1973b) reported cumulative weight gains of 3.1, 7.0 and 11.0 kg and DeRoth and Downie (1976) reported that for 2 trials, gains of 1.15, 2.85kg the first week and 3.26 and 2.59 kg the second week, and 4.29 and 3.60 kg the third week. At 3 weeks of age the pigs often weigh approximately 4.5 kg (Coalson et al., 1973; Coalson, Maxwell and Hillier, 1971; Neumann, Krider and Johnson, 1948). Cuthbertson (1969) compared weight gains of sow-reared and artificially reared pigs and reported that the latter could out-perform the sow-reared pigs.

Sow-reared pigs will normally be twice their birth weight the end of the first week (Goodwin, 1973), 3.6 times their birth weight at 2 weeks of age

(Coalson and Lecce, 1973a), 4 times their birth weight by 3 weeks of age and 6.6 times the birth weight by 4 weeks of age (Goodwin, 1973). However these pigs performed at a much lower level than this, especially the first week, although performance improved each week. Schneider and Sarett (1966a) reported that during the first week faster weight gains were obtained with sow-reared pigs than artificially reared pigs, and in succeeding weeks the pigs performed equally well. Kohler and Bohl (1966b) reported little difference in final weights of artificially- or sow-reared pigs, and Lehrer et al. (1949) reported that artificially reared pigs' growth over an 8-week period was normal. Campbell, Brough and Fell (1971) reported that artificially reared pigs were 30% lighter than sow-reared pigs at 14 days of age, and Pond et al. (1961) reported that artificially reared pigs with restricted gains had more rapid gains later but not to equal the weights of sow-reared pigs. Grummer (1954) stated that the growth rate may be mediocre and the cost of gain excessive with artificially reared pigs.

There was a wide range in the weights at any given age (Table 14). Fowler and Young (1962) reported the weights of pigs at 3 weeks of age ranged from 2.7-6.9 kg. The standard deviation of weights increased as the pigs got older (Table 15); Pettigrew, Zimmerman and Ewan (1971) also noted an increase in the standard deviation. Danielson et al. (1976) reported that the relative variability of artificially reared litters was 70-90% greater than dam-reared litters in all weights after birth, and the magnitude of the difference was mostly attributed to lower average performance of the artificially reared litters. In Table 14, the individual pig which had the lowest or highest weight at one age was not always the heaviest or lightest pig at the next age.

At one week of age the pigs averaged 3.7#, 5.0# at 2 weeks, 6.6# at 3 weeks and 9.2# at 4 weeks. This is similar to the weights of pigs fed one of the diets in experiments conducted by Danielson (1971). One week weights reported in the literature range from 1.92-2.60 kg (Danielson,1972; Cuthbertson, 1969

TABLE 14. Weight ranges of surviving pigs of different trials at different ages.

Trial	Weight (lbs.)							Age (days) at weaning of low - high weight pigs
	Age (days)							
	Birth	Weaned from sow	7	14	21	28	Weaned from liquid diet	
1	1.6 - 3.0	1.3 - 3.0	2.2 - 4.6	3.0 - 5.4	4.1 - 6.8	4.8 - 8.4	5.1 - 8.5	29 - 42
2	2.0 - 3.4	1.9 - 3.8	2.0 - 5.1	2.6 - 5.6	2.7 - 7.8	4.3 -10.2	11.0 -17.7	52 - 41
3	1.7 - 4.0	1.6 - 4.0	2.6 - 5.9	3.3 - 7.6	4.7 -10.2	6.2 -16.1	9.8 -16.2	43 - 29
4	1.6 - 3.4	1.3 - 4.0	2.0 - 4.5	3.3 - 7.3	4.8 -10.0	7.8 -13.1	11.8 -19.4	35 - 38
5	1.6 - 4.3	1.3 - 4.4	2.5 - 5.7	3.8 - 8.5	4.9 -12.4	7.2 -16.8	7.3 -19.0	31 - 31
$\bar{x}$	1.7 - 3.6	1.5 - 3.8	2.3 - 5.2	3.2 - 6.9	4.2 - 9.4	4.2 -12.9	9.0 -16.2	38 - 36

TABLE 15. Standard deviations of weights of surviving pigs in different trials at different ages.

Trial	Standard deviations (N-weighing) of weights							Standard deviations of age weaned from liquid diet
			Age (days)					
	Birth	weaned from sow	7	14	21	28	weaned from liquid	
1	.4049	.5323	.6082	.6083	.7706	1.0533	1.9929	4.6435
2	.4396	.5410	.8868	.8072	1.6187	1.8588	1.7364	6.4807
3	.6547	.6814	.7563	1.0675	1.4442	2.7683	1.4824	5.7033
4	.6013	.7785	.7126	.9979	1.3703	1.5437	1.7479	2.2867
5	.6718	.7260	.7037	1.1109	1.9200	2.5293	2.5337	2.3733
$\bar{x}$	.5545	.6520	.7335	.9184	1.4248	1.9507	1.6987	4.2975

Pettigrew, Zimmerman and Ewan, 1971) and 3-week weights range 2.70-5.78 kg (Waxler and Drees, 1972; Cuthbertson, 1969; Danielson, 1972). Some researchers report that artificially reared pigs are heavier than sow-reared pigs of the same age (Cuthbertson, 1969; Johnson, James and Krider, 1948; Weybrew et al., 1947, 1949) and Smith and Lucas (1957a) reported that artificially reared pigs had weights similar to sow-reared pigs which had access to creep feed.

A very rough estimate of the feed efficiency of pigs in Trial 5 can be made; 12.5# of SAM meal and 13.1# of Pig 45 were fed to each pig on Diet C and E, respectively. Pigs on Diet E gained 10.9# per pig and those fed Diet C gained an average of 7.8#; not adding in the 2.2# of Pig 95 fed to each pig, the feed efficiencies were calculated to be 1.21 and 1.59# of feed per pound gain. Adding in the Pig 95 used, the feed efficiencies become 1.41 and 1.88. These figures may be biased since the young pigs tended to waste feed and any creep feed or SAM pellets which were eaten were not added in. Cornelius, Harmon and Meyer (1973) also noted a high feed wastage with very young pigs.

These figures agree with several reported in the literature. Coalson, Maxwell and Hillier (1971) and Coalson et al. (1973) reported feed efficiencies ranging from 0.76-1.15 for pigs at 3 weeks of age; Anon. (1973b) reported 1.15# of milk solids were required per pound gain and 12.65# of milk replacer were fed to each pig. Zamora, Schmidt and Veum (1975) fed 3 different diets and obtained feed efficiencies ranging from 1.19-1.47; Weybrew et al. (1949) reported that 1.16 gm of milk solids were needed for each gm of liveweight gain. However, feed efficiencies as low as 0.6-0.7 gm dry matter per gm gain have been reported for pigs in the first 2 weeks of life (Lecce, 1971). There is a considerable difference in economy of gain amoung pigs (Donald, 1937b; Barber, Braude and Mitchell, 1955) and the feed efficiency becomes poorer with age (Reber, Whitehair and MacVicar, 1953); Cornelius, Harmon and Meyer (1973) report that while pigs 4 days of age had a feed efficiency of 0.66, they only had a feed efficiency of 1.82 at 55 days of age. The high feed conversion and small quantities of feed consumed by the baby pig can make it feasible to feed the expensive milk replacer.

The poor performance of the pigs in the first 3 trials was largely due to the irregular feeding schedule and the ensuing problems. However, the milk replacer was only 20.0% crude protein and the fat level was quite high (15%); also the quality of the milk replacer was questionable at times. The addition of dried skim milk to the milk replacer in Trials 2 and 3 seemed to increase average daily gain but the problem of the edema still remained.

The pigs which were fed hourly and supplemented with additional diet 3 times daily (Trial 4) performed nearly as well as pigs fed only 3 times daily, even though the pigs sufferred a devestating illness. Thus it is difficult to make a comparison between the 2 feeding regimens, although it can be said that feeding only 3 times daily, with the proper diet, can give satisfactory results.

GENERAL CONCLUSIONS AND SUMMARY

In the first 3 trials, when many problems arose with the automatic feeding device, 40 hours or more were required each week to care for the pigs. In the fourth trial the machine generally was operating; however since the pigs were also supplemented with feed 3 times daily and there was the outbreak of HEV, a true estimateof labor requirem n cannot be made for the tomatic device. In the fifth trial, when the pigs were all fed by hand 3 times daily, 20 hours or less were needed to care for the pigs; this figure could be reduced by at least half if the litter trays need to be cleaned only at the end of the trial and if the feed cups could be removed from the cages and washed, perhaps even by dishwasher.

It has been estimated that it takes $4.00-8.00 to artificially rear a pig with an automatic device, with 2-3 hours of labor required each day to care for 72 pigs (Palmer, 1976; Johnston, 1974b). It has also been calculated that it required $5.89 to artificially rear a pig if it is fed ad lib. without an automatic feeding device, and requires about 6 hours of labor to care for 72 pigs

(Anon., 1973b). Thus the automatic device will save labor unless mechanical problems arise; then the pigs may scour and must be fed by hand until the machine is repaired. With hand-feeding the mechanical feeding problems do not arise and the initial investment is lower; however labor requirements may be higher, especially when caring for a large number of pigs.

Artificially rearing of pigs can be successful with the proper management, diet and environment. Feeding 3 times per day can be as successful, or more so, than feeding with an automatic device. Not all commercial milk replacers are equal in value and not all are suitable to be fed with an automatic device. Grummer (1954) compared several commercial sow milk replacers of similar composition and obtained strikingly different results; on one the pigs developed severe diarrhea within a few hours and several pigs died while others recovered and adjusted to the diet.

Artificial rearing is not successful without proper management, and the advantages of artificial rearing are offset by the management and feeding difficulties. Inconsistent results will not pay for the time invested in the pigs; mechanical and electrical problems with an automatic feeding device can be discouraging as well as the large amount of skilled labor which is required when feeding by hand. For many producers the investment would be a waste of capital which could be more profitably invested in some other area of the operation. The producer must ask if the survival of all the pigs farrowed is worth the added cost of saving the pigs since it costs more to save the extra pigs; a commercial producer would find artificial rearing beneficial only if it was a very large operation and there were a large number of pigs being lost. If an enterprise were supplied with a sufficient number of pigs in a carefully coordinated program, it could be justified in building up the experience, organization and investment in lavor-saving equipment. Also a purebred pig producer who gets a premium for each pig may find artificial rearing profitable. However, high mortality or poor performance of the artificially reared pigs would reduce or eliminate any advantages.

Smith and Lucas (1957a) state that although there is a place for liquid milk substitutes in rearing very young orphan or surplus pigs, ~~the use of milk substitutes in rearing very young orphan or surplus pigs~~, the use of milk substitutes is too hazardous to reccomend as a general farm practice in order to increase productivity of the breeding herd. Newport (1977) also concluded that weaning before the pigs are 21 days of age cannot be generally reccomended, and the optimum age the pigs are weaned varies, depending on the availability of a suitable diet, technological ability to meet the environment required, available capital investment and the standard of stockmanship.

After carefully weighing the advantages and disadvantages of artificially rearing pigs, and deciding the necessary facilities, management and skilled labor is available, the producer may start on a small scale, feeding the pigs by hand with a minimal investment until he decides that artificial rearing is worthwhile for his operation. He may then decide to make a further investment in an automatic feeding device so he may save labor and expand the artificial rearing program's capacity.

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OBSERVATIONS AND CONSIDERATIONS WHEN ARTIFICIALLY REARING BABY PIGS IN A NON-ISOLATED ENVIRONMENT

by

KATHLEEN ANN MORIARTY

B. S., Purdue University, West Lafayette, Indiana, 1976

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ABSTRACT

An extensive literature review is made of the special problems and requirements of neonatal pigs and how these needs affect the technique of artificially rearing baby pigs in a non-isolated environment. A review of previous experimental methods, diets and problems when artificially rearing piglets is also made.

Five trials were conducted to measure and observe the effects of various diets and techniques upon artificially reared baby pigs in a non-isolated environment. Pigs were fed 24 times daily and supplementally fed 3 times daily in a fourth trial, and fed only 3 times daily in the fifth trial. Mortality rates of the 5 trials were 27.8%, 56.0%, 22.2%, 51.5% and 4.5%, with an overall mortality of 35.3%.

Birth weight was positively associated with survival rate. Pigs which were weaned from the sow while in a weight-losing condition were less likely to survive. Growth rates varied widely from trial to trial, diet to diet, and even between pigs within a trial.

Small pigs gained more, on a percentage of birth weight basis, than larger pigs, although the larger pigs always retained their weight advantage and the difference in weight increased with age. Growth of all pigs was initially slow, but the average daily gain increased with age. Growth curves were curvilinear, and the acceleration in growth varied from trial to trial. Growth of the artificially reared pigs was slower, however, than what is generally expected with sow reared pigs.