EFFECT OF VARIOUS PROTEIN SOURCES AND REGIMENS FOR
ARTIFICIALLY REARING PIGS

by

PO-HENG HSU

B.S., National Taiwan University, 1973

A MASTER'S THESIS

submitted in partial fulfillment of the

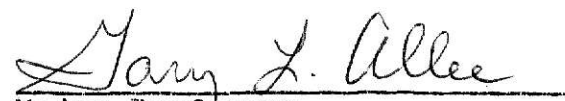requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas
1980

Approved by:

Major Professor

ACKNOWLEDGEMENT

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

Advantages of removing pigs from sows shortly after birth and feeding them artificially have been proposed (Dyrendahl et al., 1953; Braude et al., 1970). Some of these advantages can be summarized as:

Reduction in baby pig mortality - when pigs remain with the sow she has a chance to crush the piglets especially if the sow is heavy, clumsy or by nature careless. Most congenitally weak pigs die by being crushed.

Improvement in growth rate - by providing a more nutritive diet and controlled environment.

Increase in sow's productivity - by elimination of lactation and shortening of the reproductive cycle of the sow.

Decrease of infections - transmission of infections from the sow to the pigs can be reduced.

Human babies and rodents can be easily removed from their mothers at birth, but for baby pigs considerable difficulty has been met when pigs have been removed from sows at birth and raised artificially (Weybrew et al., 1949; Young and Underdahl. 1951; Leece and Matrone, 1960). Most researchers have concluded that it is necessary to give neonatal pigs colostrum to provide immunoglobulins to get a satisfactory survival rate.

Before artificial rearing can be applied in practice, the development of the digestive system enzymes of baby pigs and nutritional requirements for their growth must be understood.

Furthermore, to reduce the cost of expensive milk replacer by replacing milk protein with other cheaper protein sources and to achieve a smooth change-over from a liquid to a solid diet as early as possible without affecting the growth of the pigs were the efforts of this research.

REVIEW OF LITERATURE

Placenta and Colostrum

It is known that the construction of the placenta varies
in thickness in different animals. Some animals, e.g. horses
and swine have six layers of cells between maternal and foetal
circulations. While in guinea pigs there is only one layer
that allows a certain degree of immunization during the foetal
stage owing to the thinner foetal membrane (Edwards, 1969).
Rejnek et al. (1965) found rG type gamma globulin represented
the main immunoglobulin component of pig colostrum. Rejnek
et al. (1966) also indicated the relationship between the type
of placenta and the immunoglobulin spectrum of colostrum. They
made a comparison between the hemochorial type of human placenta
and the epitheliochorial type of pig placenta. They found that
human placenta is permeable for immunoglobulins of the rG-type
whereas the type rM and rA do not pass through this placenta
at all and represent the main components of human colostrum.
On the other hand the pig placenta is completely impermeable
for rG-globulin and it is the main component of porcine colos-
trum.

Colostrum is not absolutely necessary to the newborn
human baby nor to young rodents, because they have already been
provided with antibodies before birth. But foals and baby pigs
are immunized to a very small degree during their foetal stage
and they depend on colostrum to get passive immunity. Sterzl

et al. (1966) found that passive immunization of pregnant sows
48 hours before parturition with high titer of antibodies
resulted in no traces of antibodies being detected in newborn
piglets. During the immediate postnatal period, baby pigs have
practically no immunoglobulins (Sterzl et al., 1960).

Postnatal acquisition of passive immunity in the
neonatal piglet is by two phases: (1) uptake and (2) transport
(Clarke and Hardy, 1971; Lecce, 1973). The uptake phase is
nonselective in that macro-molecules in the lumen are inter-
nalized via pinocytosis by the enterocytes, and transported into
the blood and lymph. The antibodies in colostrum are absorbed
in an unaltered form by this.

The colostral immunoglobulins can be absorbed by baby
pigs without being altered for about the first 24 hours of life
(Speer et al., 1959). The main process of transport of immuno-
globulins into the blood in baby pig's small intestine is
conducted within about 24 to 36 hours after birth and that
corresponded with the time of the decrease of immunoglobulins
in the sow's milk (Miller et al., 1962; Yabiki et al., 1974).
Studies conducted by other researchers (Murato and Namioka,
1977) have shown colostral immunoglobulins contained in the
epithelium being observed until 2 hours after birth in the
duodenum, 24 hours in the jejunum and 48 hours in the ileum.

Antibodies are transmitted from colostrum to blood only
for a relatively short time. Lecce and Matrone (1960) showed
that intestinal absorption stops completely within 48 hours.

This result was confirmed by the studies of Asplund et al. (1962) and of Speer et al. (1959).

Lecce (1971) reported that pigs with low birth weights were easily kept by larger littermates from the first colostrum resulting in the acquisition of little colostrum and dangerously low serum immunoglobulin and reduced survival rate. It is important to make certain all pigs have equal access to the first colostrum. Bourne (1969b) and Coalson and Lecce (1973a) recommended that pigs be farrowed in a manner that would allow all pigs to be placed with the sow simultaneously with assistance at the first nursing. Morgan and Lecce (1964) found that immunoglobulin in the sow's mammary secretions drops rapidly with each ejection from the gland within the 24 hours immediately following parturition. Bourne (1969a) also reported that the immunoglobulins in sow's colostrum decreased 50% after 4 to 6 hours of nursing. He noted "the transition from colostrum to milk expressed itself not only as a fall in total whey protein levels but in changes in the percentages of the electrophoretic components." "Gammaglobulin, the major protein fraction of colostral whey at 0 hr., declined in value over the first 48 hr. to become the minor fraction of milk whey. Beta-globulin was then the major fraction." This finding agreed with the observations of Perrin (1955) and Morgan and Lecce (1964). It is suggested that early-born pigs will get colostrum rich in immunoglobulins and this may give them some physiological and immunological advantages over later-born

littermates. This may account for the variable performance
in naturally suckled pigs.

Coalson and Lecce (1973b) reported that 12 hours of
nursing was sufficient for absorption of immunoglobulins from
sow's colostrum into pigs' circulatory system to get passive
immunity when farrowed in a relatively sanitary environment.
However, for pigs from herds with a low level of sanitation 12
hours of nursing was not enough. Within 24 hours after removal
from the sow vomitting and diarrhea occurred and 40% of the pigs
died within 48 to 72 hours of weaning. They concluded that a
continuous bathing of the intestine by immunoglobulin was re-
quired by pigs farrowed in a less desirable environment and this
protection is independent of circulatory immunoglobulin. Coalson
and Lecce (1973a) reported that piglets nursing ad libitum have
absorbed substantial amounts of serum proteins by 6 hours and
a slight additional increase by 12 hours, with little change
from then on.

Payne and Marsh (1962) found that if baby pigs were fed
either on colostrum or on modified cow's milk, absorption stopped
12 hours after birth, when the epithelial cells of the intestinal
mucosa filled with r-globulin or other soluble protein. But if
the baby pigs were left to starve for 106 hours after birth they
retained the ability to absorb gammaglobulin.

There are differences in the rate of the absorption of milk
protein coming from various origins. Newborn piglets absorb Ig G
from sow's milk better than Ig G from cow's milk (Pierce, 1967).

One thing should be noted is the fact that the newborn pigs
fed on colostrum from birth have in general a weaker and slower
immune response when compared to those deprived of colostrum or
fed artificially (Smith, 1965). Immunoglobulins produced by
piglets which have received colostrum are not detectable before
approximately 10 days of age (Allen and Porter, 1973). This
shows the active immunity is inhibited to some extent by strongly-
expressed passive immunity.

The Development of the Digestive Enzyme System and Suitability
of Various Nutrients

Amylase

Amylase in saliva has little activity in the first 4
days,reaches a peak at 2 to 3 weeks of age and then decreases
(Hudman et al., 1957). Pancreatic amylase is also low at birth,
but increases rapidly up to 4 to 5 weeks of age (Walker, 1959).
Some researchers (Hartman et al., 1961; Hudman et al., 1957;
Kitts et al., 1956; Pond et al., 1971., Corring et al., 1978)
showed amylase activity increase of more than 30-fold per pan-
crease from birth to over 23 days of age. Some studies explored
the possibility of substituting starch for lactose in baby pig
milk replacer, but results showed the pigs will develop rough
coats and retarded growth (Cunningham and Brisson, 1957). Corn
starch can not be utilized properly until baby pigs reach 35
days of age (Mateo et al., 1978). Walker's (1959) data suggest
that lack of maltase in baby pig may be the limiting factor to
complete digestion of starch. Adding pancreatic amylase at 1.0%
of the starch content of the diet to feed for baby pigs did not
improve the utilization of raw corn starch (Cunningham and
Brisson, 1957). It was postulated that the amylases were des-
troyed before they reached the intestine or that the starch
required further treatment with enzymes or other materials for
its complete breakdown to glucose. Further in vitro studies
(Cunningham, 1959) indicated that the pancreatic amylase prep-

aration was extremely slow in hydrolyzing raw starch but rapidly hydrolyzed soluble starch. It suggested that the digestion of raw starch by young pigs is restricted by inability to rupture the starch granule.

Maltase

The digestion of starch requires not only alpha-amylase but also maltase. Although there is some pancreatic maltase activity, it is so low that the role of pancreatic maltase in the baby pig is of little significance (Hadman et al., 1957). Bailey et al. (1956) reported that the potential ability of baby pigs to hydrolyze maltose rose rapidly from zero at birth to 2 gm per kg of body weight per hour at 1 week of age and it increases steadily to 5 weeks of age. The rate of digestion of maltose does not approach that of glucose until the pigs are 7 days of age (Cunningham, 1959). The hydrolysis of maltose by extracts of intestine (Bailey et al., 1956; Walker, 1959) gave rates higher than those from using a stomach tube (Cunningham, 1959). If pigs have anemia this will retard the increase of maltase activity in the small intestine, but has no effect on amylase, sucrase or lactase (Walker, 1959).

Lactase

At birth, lactase is the predominant intestinal carbohydrase, but it decreases rapidly from the first to third week, remaining fairly constant thereafter (Hartman et al., 1961; Bailey et al., 1956; Sprague et al., 1963; Corring et al., 1978).

Manners and Stevens (1972) suggested that between birth and 1
week of age there was a considerable fall in lactase activity
in the proximal half of the small intestine. In 4 week-old
pigs there was no difference in lactase levels between artif-
icially reared and sow-reared pigs. After 8 weeks the lactase
level remains constant. Experiments by Becker et al. (1954a)
have shown that lactose is a very suitable carbohydrate for very
young pigs when used in a milk replacer. Sewell and West (1965)
reported pigs receiving diets containing lactose gained weight
significantly faster than those without lactose. Digestibilities
of protein and ether extract were improved by supplementation
with lactose. This partly accounts for the difference in res-
ponse to protein from a skim milk source as compared to soy bean
protein in diets of very young pig. However, diets containing
50% lactose for 9-and for 16-week old pigs will cause a moderate
diarrhea and depress feed intake and growth (Becker and Terrill
1954). Diets containing 25% lactose were satisfactory for the
16-week-old pigs. Becker et al. (1954a) reported an advantage
in favor of equal portions of lactose and corn starch in milk
replacer as compared to corn starch or lactose alone for pigs
from 7 to 35 days.

Sucrase

High mortality and severe diarrhea in baby pigs was observed
when sucrose was fed (Becker et al., 1954b). At birth, sucrase
activity has been found to be absent from the small intestine

of baby pigs or present at very low level, but it increases
rapidly with age (Bailey et al., 1956; Walker, 1959; Hartman
et al., 1961). These researchers suggested that between 3 and
4 weeks of age there is a rapid development in sucrase activity.
Differences between individual pigs and between litters in
mucosal sucrase activity was reported by Kidder et al. (1968).
Most researcher will agree that sucrose can not be used in the
diet before the pig is 1 week of age. (Aherne et al., 1969;
Becker et al., 1954b).

Proteolytic Enzymes

Very low proteinase activity can be found in newborn pig
and no rapid increase in activity until the third week after
birth (Hartman et al., 1961; Shields et al., 1977). Pepsin can
be found in the stomach of new born pigs, but it is not active
due to little hydrochloric acid (Cunningham and Brisson, 1957).
The optimum pH of pepsin activity is approximately 2. Data from
Lewis et al. (1955) showed that in suckling pigs from 1 to 35
days old the pH of the stomach contents was never below 3.5.
Walker (1959a) also reported that the stomach contents in pigs
up to 5 weeks of age were usually about a pH of 3.4. Studies
of both HCL and pepsin secretion suggest that pepsin takes
little part in digestion until pigs are more than 3 weeks of
age. However, there may be considerable variation between pigs.
Lewis et al. (1957) found that there is trypsin activity in
the pancreas and stomach mucosa from the day of birth and no

definite subsequent increase per unit weight of pancreas. Some
other results (Gorrill and Friend, 1970; Friend et al., 1970)
showed that total trypsin activity per pancreas increases
faster from 3 to 5 weeks of age than chymotrypsin. That agrees
with the observations of Pond et al. (1971a). Pond et al.
(1971a) found total chymotrypsinogen per pancreas increased more
than four times from birth to 3 weeks, during the same period
total trypsinogen activity per pancreas increased about 20 times.
Hartman et al. (1961) reported a four-fold increase of trypsin
activity per unit weight of pancreas during the first four weeks.
Corring et al. (1978) reported the level of chymotrypsinogen
in pancreatic tissue rose faster than that of trypsinogen from
birth to 3 week which is opposite to earlier results.

Numerous observations comparing milk protein with soy
protein show milk protein was superior to soy protein for baby
pigs. Various forms of soy protein have been used by different
labaratories, including isolated soybean protein (Sewell et al.,
1953; Maner et al., 1962; Pond et al., 1971b; Mateo and Veum,
1980), soybean meal (Sherry et al., 1978a; Zamora and Veum, 1978,
1979). The commonly used milk proteins are skim milk powder
(Dyrendahl et al., 1953; Sherry et al., 1978a), casein and whey
powder (Pettigrew et al., 1977; Pond et al., 1971b; Maner et al.,
1962).

Apparently milk protein is the best protein source for
baby pigs(Pekas et al., 1964; Braude et al., 1970). It is
superior to soy protein (Peo et al., 1957; Hays et al., 1959;

Maner et al., 1959, 1961; Javier and Veum, 1980; Schneider
and Sarett, 1969; Pond et al., 1971b). Fish protein is as
good as casein when used by newborn pigs (Pettigrew et al.,
1972; Pond et al., 1971b). Fish protein and milk protein are
more expensive protein sources as compared with soya protein.

Some researchers have tried to use soya protein to replace
various amounts of milk protein in milk replacer in order to
reduce the cost. Rodiguez and Young (1979) reported that baby
pigs fed a diet with 25% milk protein replacing soya protein
consumed more and gained more weight than those fed whole milk
protein diet. Replacement of more than 25% of the milk protein
with soybean meal protein significantly decreased baby pig's
performance. Zamora et al (1975) reported that a diet contained
26% soybean meal was superior to whole milk protein diet for
baby pigs. Reports by (Sherry et al., 1978; Zamora and Veum,
1978, 1979) indicated that soybean meal protein can replace
about 50% of the milk protein for artificially-reared neonatal
pigs without influencing subsequent nursery performance, but if
baby pigs are fed a diet containing less than 25% milk protein,
their subsequent performance will be depressed.

Dietary protein level needed is based on the protein
source and quality. Reber et al. (1953) reported that when
casein was the only protein source, pigs fed 25% or less protein
in the ration required more than 1 kg of dry matter to make 1 kg
of gain. But as pigs approached 8 weeks of age, a level of 20%
protein appeared to be used as efficiently as higher levels.

Pond et al. (1971b) reported that diets contained 26% C.P
and 20% lard, fish protein concentrated was equal to casein
and superior to isolated soy protein as the sole source of
protein for baby pigs from 2 to 23 days.

The protein requirement also depends on the caloric
density of the diet. Becker et al. (1954c), using diets based
on dried skim milk and containing 5% maize oil, found no
advantage in giving more than 22% protein. Similarly Manners
and McCrea's (1962) reported that with casein and a low fat
content (4% or less) 25% protein was adequate. With high fat
diets (Manners and McCrea, 1963) reported that a 30% protein
level gave optimum growth and economy of feed conversion when
dried-whole-milk-based diets contained 21% fat. Sewell et
al. (1953) reported that fastest growth and most efficient
feed utilization occurred on a 32% protein diet in which casein
was used as protein source and the diet contained 24.63% lard.

Lipase

Reports on pancreatic lipase activity by Kitts et al.
(1956) showed that there is considerable lipase activity during
the first 4 weeks of life and further increases with age. Pond
et al. (1971a) reported total activity of pancreatic lipase
increased three-fold from birth to 3 weeks of age.

Sow milk contains approximately 35% fat on a dry matter
basis (Perrin, 1954, 1955). In milk replacer the addition of
fat to the diet shows variable results. This may be due to

differences in physical forms of the fats or the level of fat
added. Kitts et al. (1956) noted that if lipids are emulsified
to give a particle diameter of less than 0.5 micron they can be
absorbed through the lacteals. An inverse relationship was found
to exist between the length of chain of the fatty acids of var-
ious fats and oils and their apparent digestibility by early-
weaned pigs (Lioyd and Crampton, 1957). Bayley and Lewis (1965)
suggested that as the level of unsaturated fatty acids in the
fat increased, there was an improvement in fat utilization by
pigs. Similar results were reported by Sherry et al. (1978b).
Bile secretion may limit absorption of fat by very young pigs
and an increase in secretion of bile may be responsible for the
increase in fat digestibility with increasing age (Lloyd et al.,
1957). Walker (1959b) found that bile volume was small in baby
pigs and increased slowly during the first 3 weeks of life.
When the pig weighed about 6.8 kg there was a sharp increase in
bile volume.

Heath and Morris (1963) demonstrated that emulsification
of fat by bile salts was necessary for hydrolysis and absorption
of fat. Frobish et al. (1969) found that adding fat to the diet
resulted in a corresponding reduction in feed intake, thereby,
decreasing the intake of other important nutrients. Thus growth
rate and feed efficiency decreased when the fat level of the
diet was increased. Wilson and Leibholz (1979) reported that as
the fat level increased from 4% to 25% from the addition of
tallow, feed intakes and ME intakes of pigs were reduced. In

the experiments of Eusebio et al. (1965), the substitution
of carbohydrates in the diets of young pigs with increasing
amounts of fat also reduced the performance of the pigs.
Leibbrandt et al. (1975) reported linear decrease in rate of
weight gain of pigs was observed as the calorie: protein ratio
increased. But when diets contained a constant calorie: protein
ratio, the rate of weight gain of pigs was not significantly
depressed by fat addition. Increasing dietary protein and fat
together did not affect the percentage carcass fat, but fat
supplementation alone increased the percentage carcass fat.

With fat-supplemented diets, protein intake may be insuff-
icient to allow full utilization of calories, if fat was sub-
stituted for an equal weight of carbohydrate. It is necessary
to increase the level of nutrients as caloric density increase,
to maintain a constant relationship between the concentration
of each nutrient and the metabolizable energy in the diet (Allee
et al., 1971).

Cline et al. (1977) proved that weight gain and ME intake
of pigs from 3 to 5 weeks of age were not adversely affected by
increasing the fat content of the diets which maintained a con-
stant calorie: protein ratio, but there existed a depression in
feed intake as the fat content of the diets increased.

Fructose

Becker et al. (1954b) found that baby pigs suffered
severe diarrhea and heavy mortality from diets containing

fructose as the carbohydrate source. Aherne et al. (1969)
also reported that very young pig (age before 6 days) could
not use fructose or sucrose as the carbohydrate source. Gins-
bury and Hers (1960) reported that the first step in the con-
version of fructose to glucose in both intestinal wall and liver
is via fructose-1-phosphate in the presence of fructokinase.
But Aherne et al. (1969) failed to find significant activity
of fructokinase in the liver and intestine in very young pig.
This result accounts for the failure of fructose and sucrose
being used by very young pigs. The fructose was absorbed pri-
marily as fructose with little or no conversion to glucose
occurring in the intestinal wall. The fructokinase activity
of the liver of the pig increased from 6 to 9 days of age.
From then on fructose can gradually be used by pigs.

Dry Diet vs Liquid Diet

Diaz et al. (1959) found that baby pigs fed liquid diets
gained faster and were more efficient than those fed dry diets.
Frobish et al. (1969) reported similar results. Braude and
Newport (1977) comparing two systems of early weaning (liquid
VS dry diet) suggested "that the growth potential of pigs weaned
at 2 days can only be fully realized when they are given a liquid
diet. Baby pigs seem physically unable to achieve as high a
dry-matter intake from dry food as when given a liquid diet."
They also indicated that the performance of pigs given the liquid
diet was better when individually caged rather than when kept

in groups. They observed that poor performance was a reflec-
tion of low feed intake and not the result of inefficient
feed conversion.

Lecce et al. (1979) found when pigs were shifted from
liquid diets to dry diets, by using a gruel two to three times
a day for a week's transition, pigs had a marked depression in
rate of gain when shifted at 9 days of age, shifting at 14
days experienced a temporary and slight decline in rate of
gain. At 30 days of age, pigs experienced no depression in
rate of gain.

Menge and Frobish (1976) used baby pigs from 3 to 31 days
of age to compare a gruel fed 3 times/day and dry mash diet fed
ad libitum. They reported no difference between these two
treatments and suggested that neonatal pigs can use all-mash
rations after receiving colostrum for 48 hours and cow's milk
for 24 hours. Wilson and Leibholz (1979) reported an average
daily gain of 220 gm/day and 0.8 g DM intake/g gain between 7
and 28 days of age when pigs were reared artificially on dry
diets. This suggest that successful early weaning of pigs on a
commercial scale can be done by using a dry pelleted diet which
can eliminate the need of sophisticated liquid feeding equipment.

GENERAL PROCEDURES

Animals

All pigs were from the university swine herd. In trial
1, pigs were purebred Yorkshire. In trial 2, crossbred pigs
(Yorkshire X Hampshire X Duroc) were used. Newborn pigs were
weighed, needle teeth clipped, ears notched, tails docked and
given a 1 cc. iron dextrin shot. Pigs were removed from sows
15-24 hours after birth and assigned to treatments by birth
weight and litter. All pigs received a second 1 cc. intramus-
cular injection of iron dextrin at 7 days of age.

Housing and Equipment

Pigs were reared in individual wire cages (60x30x30cm)
in a 6x9m room located at the university swine farn. Each
cage was equipped with a 120 ml capacity plastic cup. A gas
heater was used to maintain the room temperature at 32°C. An
overhead exhaust fan was operated only in the day-time.

Feeding

Pigs were removed from sows and put in the individual
cages for at least 6 hours with no water or milk replacer to
make them thirsty. Most pigs readily consumed the first feeding
of cow colostrum after the 6 hour fast. The first day pigs
were fed every 6 hours, the second day every 8 hours, and day
3-21 they were fed every 12 hours. At every feeding, the feed
left in the cups from the previous feeding was discarded and

the cups were washed. Feed intake was in accordance with appetite and individual consumption was recorded.

The cow colostrum used in this study was from first and second milkings from the university dairy herd. Fresh cow colostrum was frozen in plastic containers and thawed as needed every day. Additional cow colostrum was freeze-dried and stored under refrigeration for use in trial 2. Liquid diets were hand fed as 20% solid-concentration. No water, in addition to that in the milk replacer, was supplied.

Management

Scour scores were recorded daily and were based on a score of 0 to 3 (0 = normal feces, 1 = loose feces, 2 = liquid and some solids together, 3 = watery scour). Pigs were not treated for scours in trial 1. In trial 2, Soweena[R] itself contained 381 grams/ton neomycin sulfate. As pigs got scours, their feed was reduced and the milk replacer was diluted by adding extra water. Pigs were weighed initially and at weekly intervals. Feed intake and feed efficiency were calculated only in liquid-feed treatments. All pigs were moved to a conventional nursery at 21 days of age.

Statistical Analysis

Data for average gain, average daily gain and apparent protein digestibility were analyzed statistically by means of analysis of variance (ANOVA) and least significant difference (LSD).

PROCEDURES OF INDIVIDUAL TRIALS

Trial 1

Sixty pigs from seven litters were allotted to five treat-
ments to evaluate replacing various levels of milk protein with
soy protein. Their initial weight averaged 1.36 kg. All pigs
were allowed to suckle sows for 15-24 hours before they were
taken to individual cages. Four levels of soy protein and an
all milk protein milk replacer prepared by Land O'Lakes, Inc.
were used. Each pig received 125 ml cow colostrum daily the
first 3 days. Treatments differed in the sources of protein
(1) all milk protein; (2) 25% modified soy protein and 75% milk
protein; (3) 50% modified soy protein and 50% milk protein; (4)
75% modified soy protein and 25% milk protein; (5) 50% soybean
flour protein and 50% milk protein. Milk replacers contained
28% protein and 10% fat on dry matter basis. Modified soy pro-
tein was the patented 52% protein soy flour of Land O'Lakes, Inc.
(see Appendix).

During the trial, three healthy pigs from each treatment
were chosen for the digestion trial. Feces were collected for
4 consecutive days and assayed.

Trial 2

Fifty pigs from six litters were allotted to five treat-
ments to study the effects of supplementing with cow colostrum
and transition from liquid to dry diets. Their initial weights
averaged 1.18 kg. All pigs nursed the sow for 15-24 hours before

they were taken to individual cages. A commercial milk
replacer (Soweena[R] - Foremost Company) was used. Twenty pigs
were assigned to dry-diet treatment and switched from liquid
feed to crumble form from 7 days of age. A 3 day transition
period was used. Pigs on the dry diet were group fed with 6
to 7 pigs per pen from day 10 through day 21 and water was
supplied ad libitum. Treatments were: (1) No cow colostrum
supplied, milk replacer in liquid form; (2) 20 gm freeze-dried
cow colostrum day 1-3, milk replacer in crumble form day 7-21;
(3) 20 gm freeze-dried cow colostrum day 1-3, milk replacer in
liquid form; (4) 125 ml cow colostrum day 1-3, milk replacer in
crumble form day 7-21; (5) 125 ml cow colostrum day 1-3, milk
replacer in liquid form.

During transition period (from day 7 to day 10), a pre-
ference test was conducted between pellet and crumbles which
were supplied to pigs simultaneously.

RESULTS

Trial 1

The results of trial 1 are shown in Table 2. Replacing milk protein with soy protein (up to 75% replacement) did not result in any significant differences in pig performance. Differences in average daily gain of pigs fed 50% modified soy protein and 50% soy bean flour were not significant. Average daily gains in the third week exceeded 200 grams per day for all treatments.

Substituting modified soy protein for 25% of the milk protein resulted in better performance in terms of average daily gain, feed efficiency, however it was not statistically signif- icant. Pigs on the all milk protein diet showed a greater in- cidence of scours throughout the trial. Reduction in scour problem due to soy protein in baby pig milk replacer was evident throughout the trial.

The results of digestibility trial are shown in Table 3. The apparent protein digestibilities exceeded 90% for all treat- ments with the all milk protein diet being superior to other diets. The lowest protein digestibility was observed on the diet with 75% modified soy protein. Difference in digestibility between 50% modified soy protein and 50% soy flour was not sig- nificant.

Trial 2

The results of trial 2 are shown in Table 4. Supplementation with fresh or freeze-dried cow colostrum to newborn pigs after nursing sows for 15-24 hours did not show any advantage in this trial. Average daily gains in first week were similar for all treatments. Cow colostrum did not affect survival rate. Transition from liquid to dry diets at 7 days of age and group-feeding from 10 days of age on did not result in significant difference by the end of the 21 day trial. This regimen decreased average daily gain during week 2 and caused a greater incidence of scours. However, during the third week, pigs on dry diets and group-fed gained significantly faster with less scours than pigs fed liquid diets and were able to make up the reduced gain during the transition period in week 2.

During transition period, pigs on dry diets showed anxiety and jumped in cages when other pigs were receiving liquid diets. In that condition, the transition from liquid to dry diets apparently was difficult. When pigs on dry diets were group fed from 10 days of age, moderate fighting between pigs was noted.

TABLE 1. COMPOSITION OF MILK REPLACERS. (Trial 1 and 2)

Ration	Milk Replacer[a]					Milk Replacer[b]	
	1	2	3	4	5		
Milk Protein %	100	75	50	25	50	Crude Protein %	25
Modified Soy Protein %	0	25	50	75	0	Crude Fat %	10
Soybean Flour Protein %	0	0	0	0	50	Lactose %	50
Dry Matter %	96	96	96	96	94	Cal./gm	5502
Crude Protein %[c]	28	28	28	29	29	Neomycin Sulfate	381gm/ton
Crude Fat %[c]	10	10	9.5	10	9.5		
Crude Fiber %[c]	.20	.30	.25	.39	.44		
Cal./gm[c]	4330	4300	4380	4300	4260		
Calcium %	.84	.85	.86	.84	.84		
Phosphorus %	.77	.77	.79	.76	.78		

[a]Prepared by Land O'Lakes, Inc.

[b]Soweena brand milk replacer by Foremost.

[c]Analyzed data on dry matter basis.

TABLE 2. PERFORMANCE OF PIGS FED MILK REPLACERS CONTAINING VARIOUS SOURCES AND LEVELS OF SOY PROTEIN. (Trial 1)

Modified Protein:	0%	25%	50%	75%	50% Soybean-flour protein
Milk Protein:	100%	75%	50%	25%	50%
No. of Pigs Started	12	12	12	12	12
Mortality	1	0	1	1	1
Ave. Initial Wt. (kg)[a]	1.34±0.3	1.37±0.3	1.37±0.4	1.36±0.3	1.35±0.3
Ave. Final Wt. (kg)[a]	4.54±0.8	4.73±0.8	4.68±1.0	4.27±0.9	4.40±0.9
Ave. Gain (kg)[a]	3.20±0.7	3.35±0.5	3.30±0.7	2.90±0.7	3.04±0.6
Ave. Daily Gain (gm)[a]					
WK. 1	100±24	103±22	97±28	94±23	85±27
WK. 2	148±47	135±34	144±35	113±58	128±33
WK. 3	206±105	238±68	222±66	210±62	220±58
WK. 1-3	151±31	159±24	154±33	139±32	144±31
Total Feed Consumed (kg)	30.5	34.2	32.2	30.9	30.7
Total Gain (kg)	35.0	40.0	35.7	32.1	33.4
Feed Efficiency (Feed/Gain)	0.87	0.85	0.9	0.96	0.92
Cumulative Scour Score[b]					
WK. 1	27 (5)	2 (1)	2 (1)	3 (2)	4 (2)
WK. 2	44 (4)	23 (8)	10 (3)	30 (8)	5 (2)
WK. 3	40 (5)	10 (2)	8 (3)	13 (4)	11 (3)
WK. 1-3	111	35	20	46	20

[a]Mean ± standard error.

[b]Figures in parentheses mean the number of pigs had scours.

TABLE 3. APPARENT DIGESTIBILITIES OF DIETS FED TO PIGS. (Trial 1)[a]

					50% Soybean-flour protein
Modified Protein:	0%	25%	50%	75%	50%
Milk Protein:	100%	75%	50%	25%	50%
No. of Pigs	3	3	3	3	3
Protein %[b]	95.3 ± 1.2^{c}	93.6 ± 2.3^{cd}	91.8 ± 1.5^{de}	89.6 ± 0.5^{e}	93.0 ± 1.7^{cd}
Dry Matter %[b]	97.2 ± 1.4	94.2 ± 2.8	95.4 ± 2.8	92.5 ± 1.8	94.3 ± 1.6

[a]Each value is the mean of three pigs from day 11 to 14.

[b]Mean $\pm$ standard error.

[cde]Means in the same line with different superscripts are significantly different ($P<.05$).

TABLE 4. PERFORMANCE OF PIGS FED MILK REPLACERS IN LIQUID OR DRY FORM, WITH OR WITHOUT COW COLOSTRUM SUPPLEMENTED FOR THREE DAYS. (Trial 2)

Cow Colostrum:	None	Freeze-dried	Freeze-dried	Fresh	Fresh
Form of Diets:	Liquid	Dry	Liquid	Dry	Liquid
No. of Pigs Started	10	10	10	10	10
Mortality	0	1	1	0	1
Ave. Initial Wt. (kg)[d]	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.2
Ave. Final Wt. (kg)[d]	4.2 ± 1.2	4.2 ± 1.0	4.2 ± 1.0	4.3 ± 0.8	4.4 ± 1.0
Ave. Gain (kg)[d]	3.0 ± 1.1	3.0 ± 0.8	3.0 ± 0.9	3.1 ± 0.8	3.2 ± 0.9
Ave. Daily Gain (gm)[d]					
WK. 1	117 ± 32	117 ± 26	119 ± 30	124 ± 25 ab	119 ± 20
WK. 2	160 ± 57 a	125 ± 55 b	158 ± 46 a	140 ± 41 ab	163 ± 65 a
WK. 3	150 ± 77 c	195 ± 60 a	145 ± 88 c	184 ± 77 ab	171 ± 51 b
WK. 1-3	142 ± 65	146 ± 40	141 ± 43	149 ± 35	151 ± 41
Cumulative Scour Score[e]					
WK. 1	6 (2)	0 (0)	0 (0)	6 (2)	3 (1)
WK. 2	29 (3)	35 (4)	22 (2)	15 (1)	34 (4)
WK. 3	25 (5)	0 (0)	26 (2)	0 (0)	14 (3)
WK. 1-3	60	35	48	21	51

abc Means in the same line with different superscripts are significantly different (P<.05).

d Mean ± standard error.

e Figures in parentheses mean the number of pigs had scours.

DISCUSSION

The results of trial 1 indicated there was no statistically significant difference in pig performance or mortality as milk protein in diets was partially replaced by soy protein for artificially reared newborn pigs. Results from other workers (Sherry et al., 1978a; Zamora and Veum, 1978, 1979; Rodriguez and Young, 1979; Mateo and Veum, 1980) have suggested average daily gain and gain to feed ratios decreased as the percentage of milk protein in the diet decreased. Sherry et al. (1978a) reported pig performance on diets containing 25% or less milk protein from 2 to 23 days of age was severely depressed. Protein sources in their study came from corn, soybean meal and skim milk powder and diets contained only 21% crude protein. In this trial, the protein sources came from casein and modified soy protein or soybean flour only and diets contained 28% crude protein. The milk protein in diets in studies conducted by Mateo and Veum (1980) was completely replaced by soy protein. Zamora and Veum (1978, 1979) suggested diets for newborn pigs contain 26% crude protein, up to 48% C.P provided by soybean meal gave acceptable performance (89 ± 20 gram average daily gain for 21 days trial). In this trial, 154 gram and 144 gram average daily gain were shown as 50% modified protein or soybean flour added in diets respectively. Data from the studies of Rodriguez and Young (1979) indicated pigs showed better performance when 25% milk protein was replaced by soy protein in milk replacers for baby

pigs. This is similar with what we found in this trial. Both milk and soy protein sources produced similar performance after 2 weeks of age. Similar results were indicated by Zamora and Veum (1978, 1979) and Mateo and Veum (1980). Incidence of scours was greatest on the all milk protein diet with no difference between the modified soy protein and soy flour.

In trial 2, no advantage was found from supplementing fresh or freeze-dried cow colostrum to newborn pigs after nursing sows for 15-24 hours. Coalson and Lecce (1973b) reported 12 hours nursing was enough to give adequate immunity to pigs from herd with a high level of sanitation. Haye and Kornegay (1979) reported newborn pigs allowed 12 hours nursing and raised artificially resulted in a slightly reduced antibody response and lower serum Ig M but not Ig G and Ig A with similar weight gain (3.14 kg VS 2.84 kg) at 20 days of age for sow-and artificially-reared pigs. In our studies, pigs in both trials gained an average of 3 kg to 21 days of age. The results in trial 2 showed an evident depression in growth during the transition from the liquid to dry diet. But during week 3 a significantly compensatory growth resulted in an equal gains at 21 days of age.

Most pigs with scour recovered as diet intake was reduced and diet concentration was diluted. Transition induced a greater incidence of scours but did not show a lasting effect. Pigs on the dry diet had no scours during week 3.

Apparently the physical characteristics of dry diets and age of pigs are important factors to affect the success of

transition from a liquid to a dry diet. A high lactose level in milk replacer causes a hard pellet that is not readily accepted by pigs at 7 days of age. In this trial, the same dry diet in pellet form or crumble form was provided during transition. Pigs had no problem in consuming the diet in crumble form. Most pellets were pushed out of feeder by pigs' snouts. Results from Braude and Newport (1977) showed intake from the pelleted diet was considerably less than that from the liquid diet. Menge and Frobish (1976) reported newborn pigs from 4 days of age could utilize all-mash ration as well as liquid diet.

The results of trial 2 suggest that pigs can be switched from a liquid to a dry diet at 7 to 10 days of age and group-fed with similar performance as individually fed pigs receiving a liquid diet. The use of a dry diet with group feeding greatly decreases the labor involved in artificially rearing newborn pigs.

SUMMARY

Two trials using 110 pigs were conducted to investigate the growth response of newborn pigs to various levels of soy protein replacing milk protein in milk replacers, the use of fresh or freeze-dried cow colostrum and use of a liquid or dry diet. Pigs were removed from sows 15-24 hours after birth and reared artificially. Partial replacements of milk protein by modified soy protein or soybean flour did not significantly affect growth rate. Substitution of 25% milk protein by modified soy protein resulted in a slightly greater gain and decreased incidence of scours. Differences in performance between pigs fed 50% modified soy protein and 50% soy flour protein diets were not significant. Up to 75% milk protein replaced by modified soy protein did not show significant differences. Pigs on all milk protein diets exhibited a greater incidence of scours.

There was no advantage from supplementing the milk replacer with fresh or freeze-dried cow colostrum. Slightly depressed growth and moderate scour could be seen as pigs were shifted from liquid diets to dry diets at 7 days of age, but later a compensatory growth resulted in equal weight gains for all treatments at 3 weeks of age.

This study indicates the feasibility of rearing newborn pigs on dry diets from 7 days of age, group-feeding in a conventional nursery with similar performance as individually fed pigs receiving a liquid diet. It also shows that soy products are potentially an economical protein source for pig milk replacers.

APPENDIX

Modified soy protein is the patented product of Land O'Lakes, Inc. According to U.S. patent No. 4079155, that process involves subjecting the soybean materials (such as full-fat, low-fat or defatted cracked beans, flakes, grits or flour) in a thin layer to alcohol vapor or alcohol-water vapor, under a temperature of at least about $100^{o}C$ and at superatmospheric pressure for the required time while continuously permitting slow release of vapor from the system. Under these temperature and pressure conditions, certain of the undesirable flavor constituents are volatilized and tend to be carried off with the escaping vapors. A pressure of approximately 5 to 15 psi gauge, and a temperature of about 100° to $115^{o}C$ for a period of approximately twenty minutes to one-half hour is required for fully effective treatment.

The protein dispersibility index (PDI) is a measure of the solubility in water of the protein content of the soybean material, and decreases with increasing denaturation. The PDI of the raw soybean material is generally about 90. Products by that process have a PDI of about 20. They claim that the taste of their product is far superior to products made by conventional methods employed for increasing the digestibility of soybeans.

Aherne, F., V.W. Hays, R.C. Ewan and V.C. Speer. 1969.
Absorption and utilization of sugars by the baby pigs.
J. Anim. Sci. 29:444.

Allee, G.L., D.H. Baker and G.A. Leveille. 1971. Fat utili-
zation and lipogenesis in the young pig. J. Nutr.
101:1415.

Allen, W.D. and P. Porter. 1973. The relative distribution
of Ig M and Ig A cells in intestinal mucosa and lymphoid
tissues of the young unweaned pig and their significance
in ontogenesis of secretory immunity. Immunol. 24:493.

Asplund, J.M., R.H. Grummer and P.H. Phillips. 1962. Absorp-
tion of colostral gamma globulins and insulin by the
newborn pig. J. Amin. Sci. 21:412.

Bailey, C.B., W.D. Kitts and A.J. Wood. 1956. The development
of the digestive enzyme system of the pig during its
preweaning phase of growth; B. Intestinal lactase,
sucrase and maltase. Can. J. Agr. Sci. 36:51.

Bayley, H.S. and D. Lewis. 1965. The use of fats in pig
feedings. II. The digestibility of various fats and
fatty acids. J. Agr. Sci. 64:373.

Becker, D.E., D.E. Ullrey and S.W. Terrill. 1954a. A com-
parison of carbohydrates in a synthetic milk diet for the
baby pig. Arch. Biochem. Biophys. 48:178.

Becker, D.E., D.E. Ullrey, S.W. Terrill and R.A. Notzold.
1954b. Failure of the newborn pig to utilize dietary
sucrose. Science 120:345.

Becker, D.E., D.E. Ullrey and S.W. Terrill. 1954c. Protein
and amino acid intakes for optimum growth rate in the
young pig. J. Anim. Sci. 13:346.

Becker, D.E. and S.W. Terrill. 1954. Various carbohydrates in
a semipurified diet for the growing pig. Arch. Biochem.
Biophys. 50:399.

Bourne, F.J. 1969a. Studies on colostral and milk whey proteins
in the sow. I. The transition of mammary secretion from
colostrum to milk with natural suckling. Anim. Prod.
11:337.

Bourne, F.J. 1969b. Studies on colostral and milk whey proteins
in the sow. II. The effect of delayed suckling on colos-
trum and milk whey proteins. Anim. Prod. 11:345.

Braude, R., K.G. Mitchell, M.J. Newport and J.W.G. Porter. 1970. Artificial rearing of pigs. I. Effect of frenquency and level of feeding on performance and digestion of milk proteins. Brit. J. Nutr. 24:501.

Braude, R. and M.J. Newport. 1977. A note on a comparison of two systems for rearing pigs weaned at 2 days of age, involving either a liquid or a pelleted diet. Anim. Prod. 24:271.

Clarke, R.M. and R.N. Hardy. 1971. Histological changes in the small intestine of the young pig and their relation to macromolecular uptake. J. Anat. 108:63.

Cline, T.R., J.A. Coalson, J.G. Lecce and E.E. Jones. 1977. Utilization of fat by baby pigs. J. Anim. Sci. 44:72.

Coalson, J.A. and J.G. Lecce. 1973a. Influence of nursing intervals on changes in serum proteins (immunoglobulins) in neonatal pigs. J. Anim. Sci. 36:381.

Coalson, J.A. and J.G. Lecce. 1973b. Herd differences in the expression of fatal diarrhea in artificially reared piglets weaned after 12 hours VS 36 hours of nursing. J. Anim. Sci. 36:1114.

Corring, T., A. Aumaitre and G. Durand. 1978. Development of digestive enzymes in the piglet from birth to 8 weeks. Nutr. Metab. 22:231.

Cunningham, H.M. and G.J. Brisson. 1957. The effect of amylases on the digestibility of starch by baby pigs. J. Animal. Sci. 16:370.

Cunningham, H.M. 1959. Digestion of starch and some of its degraduation products by newborn pigs. J. Anim. Sci. 18:964.

Diaz, F., V.C. Speer, P.G. Homeyer, V.W. Hays and D.V. Catron. 1959. Comparative performances of baby pigs fed infant and baby pig diets. J. Nutr. 68:131.

Dycendahl, S., O. Swahn, G. Bjorck and L. Hellving. 1953. Artificial raising of baby pigs. Acta Agri. Scan. III (3):334.

Edwards, R.G. 1969. Immunology and reproduction published by the International planned parenthood Federation. (London)

Eusebio, J.A., V.W. Hays, V.C. Speer and J.T. McCall. 1965. Utilization of fat by young pigs. J. Anim. Sci. 24:1001.

Frobish, L.T., V.W. Hays, V.C. Speer and R.C. Ewan. 1969. Effect of diet form and emulsifying agents on fat utilization by young pigs. J. Anim. Sci. 29:320.

Ginsbury, V. and H.G. Hers. 1960. On the conversion of fructose to glucose by guinea pig intestine. Biochem. Biophys. Acta. 38:427.

Gorrill, A.D.L. and D.W. Friend. 1970. Pancreas size and trypsin and chymotrypsin activities in the pancreas and intestinal contents of pigs from birth to five weeks of age. Can. J. Physiol. Pharmacol. 48:745.

Hartman, P.A., V.W. Hays, R.O. Baker, L.H. Neagle and D.V. Catron. 1961. Digestive enzyme development in the young pig. J. Anim. Sci. 20:114.

Haye, S.N. and E.T. Kornegay. 1979. Immunoglobulin G, A and M and antibody response in sow-reared and artificially-reared pigs. J. Anim. Sci. 48:1116.

Hays, V.W., V.C. Speer, P.A. Hartman and D.V. Catron. 1959. The effect of age and supplemental amino acids on the utilization of milk and soya protein by the young pig. J. Nutr. 69:179.

Heath, T.J. and Bede Morris. 1963. The role of bile and pancreatic juice in the absorption of fat in ewes and lambs. British J. Nutr. 17:465.

Hudman, D.B., D.W. Friend, P.A. Hartman, G.C. Ashton and D.V. Catron. 1957. Digestive enzymes of the baby pig: Pancreatic and salivary amylase. J. Agri. Food Chem. 5:691.

Javier, P.M. and T.L. Veum. 1980. Utilization of casein or isolated soybean protein supplemented with amino acids and glucose or lactose by neonatal piglets reared artificially. J. Anim. Sci. 50:869.

Kidder, D.E, M.J. Manners, M.R. McCrea and A.D. Osborne. 1968. Absorption of sugars by the piglet. Br. J. Nutr. 22:501.

Kitts, W.D., C.R. Bailey and A.J. Wood. 1956. The development of the digestive enzyme system of the pig during its preweaning phase of growth. A. Pancreatic amylase and lipase. Can. J. Agri. Sci. 36:45.

Lecce, J.G. and G. Matrone. 1960. Porcine neonatal nutrition: The effect of diet on blood serum proteins and performance of the baby pig. J. Nutr. 70:13.

Lecce, J.G. 1971. Rearing neonatal piglets of low birth weight with an automatic feeding device. J. Anim. Sci. 33:47.

Lecce, James G. 1973. Effect of dietary regimen on cessation uptake of macro-molecules by piglet intestinal epithelium (closure) and transport to the blood. J. Nutr. 103:751.

Lecce, J.G., W.D. Armstrong, P.C. Crawford and G.A. Ducharme. 1979. Nutrition and management of early weaned piglets: liquid VS dry feeding. J. Anim. Sci. 48:1007.

Leibbrandt, V.C., Ewan, R.C., Speer, V.C. and Zimmerman, D.R. 1975. Effect of age and calorie protein ratio on performance and body composition of baby pigs. J. Anim. Sci. 40:1070.

Lewis, C.J., D.V. Catron, C.H. Liu, V.C. Speer and G.C. Ashton. 1955. Enzyme supplementation of baby pig diets. J. Agr. Food Chem. 3:1047.

Lewis, C.J., P.A. Hartman, C.H. Liu, R.O. Baker and D.V. Catron. 1957. Digestive enzymes of the baby pig: pepsin and trypsin. J. Agri. Food Chem. 5:687.

Lloyd, L.E. and E.W. Crampton. 1957. The relation between certain characteristics of fats and oils and their apparent digestibility by young pigs young Guinea pigs and pups. J. Anim. Sci. 16:377.

Lloyd, L.E., Z.W. Crampton and V.G. Mackay. 1957. The digestibility of ration nutrients by three VS seven-week old pigs. J. Anim. Sci. 16:383.

Maner, J.H., W.C. Pond and R.S. Lowrey. 1959. Effect of proteolytic enzyme supplementation to simulated-milk diets on weight gains and protein digestibility in baby pigs. J. Anim. Sci. 18:1487 (Abstr.)

Maner, J.H., W.G. Pond and J.K. Loosli. 1961. Utilization of soybean protein by baby pigs and by rats. J. Anim. Sci. 201:614.

Maner, J.H., W.G. Pond, J.K. Loosli and R.S. Lowery. 1962. Effect of isolated soybean protein and casein on the gastric pH and rate of passage of food residues in the baby pigs. J. Anim. Sci. 21:49.

Manners, M.J. and M.R. McCrea. 1962. Protein requirement of baby pigs on low-fat diets. Brit. J. Nutr. 16:475.

Manners, M.J. and M.R. McCrea. 1963. Protein requirement of baby pigs. 2. Requirement on high-fat and effect of replacing carbohydrate by fat. Brit. J. Nutr. 17:357.

Manners, M.J. and J.A. Stevens. 1972. Changes from birth to maturity in the pattern of distribution of lactase and sucrase activity in the mucosa of the small intestine of pigs. Brit. J. Nutr. 28:113.

Mateo, J.P., R.C. Lauxen and T.L. Veum. 1978. Utilization of glucose, lactose, sucrose and corn starch by baby pigs reared artificially. Abstr. Am. Soc. Anim. Sci. 70th. Ann. Mtng. p. 309.

Mateo, J.P. and T.L. Veum. 1980. Utilization of casein or isolated soybean protein supplemented with amino acids and glucose or lactose by neonatal piglets reared artifically. J. Anim. Sci. 50:869.

Menge, Henry and L.T. Frobish. 1976. Nutritional studies with the early weaned neonatal pig. J. Anim. Sci. 42:99.

Miller, E.R., B.G. Harmon, D.E. Ullery, D.A. Schmidt, R.W. Luecke and J.M. Hoefer. 1962. Antibody absorption, retention and production by the baby pig. J. Anim. Sci. 21:309.

Morgan, D.O. and J.G. Lecce. 1964. Electrophoretic and immunoelectrophoretic analysis of the proteins in the sow's mammary secretions throughout lactation. Res. Vet. Sci. 5:332.

Murata, H. and S. Namioka. 1977. The duration of colostral immunoglobulin uptake by the epithelium of the small intestine of neonatal piglets. J. Comp. Pathol. 87:431.

Payne, L.C. and C.L. Marsh. 1962. Gamma globulin absorption in the baby pig: the nonselective absorption of heterologous globulins and factors influencing absorption time. J. Nutr. 76:151.

Pekas, J.C., V.W. Hays and A.M. Thompson. 1964. Exclusion of the exocrine pancreatic secretion: effect on digestibility of soybean and milk protein by baby pigs at ages. J. Nutr. 82:277.

Peo, E.R. Jr., V.W. Hays, C.C. Ashton, V.C. Speer, O.H. Lui and D.V. Catron. 1957. Application of the protein

depletion - repletion technique in baby pig feeding experiments. I. A comparison of levels and sources of proteins for baby pigs. J. Nutr. 62:465.

Perrin, D.R. 1954. The composition of sow's milk during the course of lactation. J. Dairy Res. 21:55.

Pettigrew, J.E., B.G. Harmon; A.H. Jensen and D.H. Baker. 1972. Source and level of protein for baby pigs. J. Anim. Sci. 35:1109 (abstr.).

Pettigrew, J.E., B.G. Harmon, S.E. Curtis, S.G. Cornelius, H.W. Norton and A.H. Jensen. 1977. Milk proteins for artificially reared piglets. III. Efficacy of sodium caseinate and sweet dried whey. J. Anim. Sci. 45:261.

Pierce, A.E. and M.W. Smith. 1967. The intestinal absorption of pig and bovine immune lactoglobulin and human serum albumin by the new-born pig. J. Physiol. 190:1.

Pond, W.G., J.T. Snook, D.McNeill, W.I. Snyder and B.R. Stillings. 1971a. Pancreatic enzyme activities of pigs up to three weeks of age. J. Anim. Sci. 33:1270.

Pond, W.G., W. Snyder, E.F. Walker. Jr., B.R. Stillings and V. Sidwell. 1971b. Comparative utilization of casein, fish protein concentrate and isolated soybean protein in liquid diets for growth of baby pigs. J. Anim. Sci. 33:587.

Reber, E.F., C. Whitehair and R. MacVicar. 1953. The effect of level of protein fed baby pigs. J. Nutr. 50:451.

Rejnek, J., O. Kotynek and J. Kostka. 1965. Contribution of the structural characterization of gamma globulin from pig colostrum. Folia Microbiol. 10:327.

Rejnek, J., J. Kostka and J. Travnicek. 1966. Studies on the immunoglobulin spectrum of porcine serum and colostrum. Folia Microbiol. 11:173.

Rodriguez, J.P. and L.G. Young. 1979. Replacement of milk protein with protein from soybean meal in diets for pigs weaned at one week of age. Effects on performance and on pancreatic enzymes development. Am. Soc. Anim. Sci. 1979 Meeting Abstr. p. 252.

Schneider, D.L. and H.F. Sarett. 1969. Growth of baby pigs fed infant soybean formulas. J. Nutr. 98:279.

Sewell, R.F., B.E. Sheffy, R.G. Eggert and J.K. Loosli. 1953.

Studies on the protein requirement of suckling pigs. J. Anim. Sci. 12:597.

Sewell,R.F. and J.P. West. 1965. Some effects of lactose on protein utilization in the baby pig. J. Anim. Sci. 24: 239.

Sherry, M.P., M.K. Schmidt and T.L. Veum. 1978a. Performance of neonatal piglets mechanically fed diets containing corn, soybean meal and milk protein. J. Anim. Sci. 46:1250.

Sherry, M.P., M. Schmidt and T. Veum. 1978b. Dietary protein to calorie ratios and-fat sources for neonatal piglets reared artificially with subsequent performance. I. Performance. J. Anim. Sci. 46:1259.

Shields, R., Jr., K. Ekstrom and D. Mahan. 1977. Digestive enzyme development in the baby pig from birth to ten weeks of age. J. Anim. Sci. 45, Suppl. 1. p. 108.

Smith, A.N. and D.G. Ingnam. 1965. Immunological responses of young animal. Can. Vet. J. 6:226.

Speer, V.C., H. Brown, L. Ouinn and D.V. Catron. 1959. The cessation of antibody absorption in the young pig. J. Immunol. 83:632.

Sprague, J.I., D.E. Ullrey., D.G. Waddill., E.R. Miller., C.L. Zutant and J.A. Hoeffer. 1963. Intestinal lactase, alkaline and acid phosphatase in the swine foetus and newborn pig. J. Anim. Sci. 22:121.

Sterzl, J., J. Kostka, I. Riha and L. Mandel. 1960. Attempts to determine the formation and character of gamma globulin and of natural and immune antibodies in young pigs reared without colostrum. Folia Microbol. 5:29.

Sterzl, J., J. Rejnek and J. Travnicek. 1966. Impermeability of pig placenta for antibodies. Folia Microbiol. 11:7.

Walker, D.M. 1959a. The development of the digestive system of the young animal I. Tissue weights, dry matter of tissues, total acidity and chloride content of stomach contents in the young pig. J. Agric. Sci. 52:352.

Walker, D.M. 1959b. The development of the digestive system of the young animal II. Carbohydrase enzyme development in the young pig. J. Agri. Sci. 52:357.

Weybrew, J.A., H.A. Stewart, G. Matrone and W. J. Peterson.

1949. Supplemented milk diets for young pigs in cages. J. Anim. Sci. 8:207.

Wilson, R.H and Jane Leibholz. 1979. Protein, fat and carbo-hydrates in the diets of pigs between 7 and 28 days of age. Anim. Prod. 28:391.

Yabiki, T., M. Kashiwazaki and S, Namioka. 1974. Quantitative analysis of 3 classes of immunoglobulins in piglet serum and milk of sows. Am. J. Vet. Res. 35:1483.

Young, G.A., Jr. and N.R. Underdahl. 1951. A diet and technic for starting pigs without colostrum. Arch. Biochem. Biophys. 32:449.

Zamora, R.G., M.K. Schmidt and T.L. Veum. 1975. Protein levels and sources for neonatal piglets. J. Anim. Sci. 41:331 (Abstr.).

Zamora, R.G. and T.L. Veum. 1978. Various levels of soybean meal as replacement for dried skim milk for artificially reared neonatal pigs. Nutr. Rep. Internat'l. 18:495.

Zamora, R.G. and T.L. Veum. 1979. The effects of increasing the levels of soybean protein in the diets for artifically reared neonatal pigs. Nutr. Rep. Internat'l. 19:49.

EFFECT OF VARIOUS PROTEIN SOURCES AND REGIMENS FOR
ARTIFICIALLY REARING PIGS

by

PO-HENG HSU

B.S., National Taiwan University, 1973

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas
1980

ABSTRACT

Two trials using 110 pigs were conducted to investigate the growth response of newborn pigs to various levels of soy protein replacing milk protein in milk replacers, the use of fresh or freeze-dried cow colostrum and use of a liquid or dry diet. Pigs were removed from sows 15-24 hours after birth and reared artificially. Partial replacements of milk protein by modified soy protein or soybean flour did not significantly affect growth rate. Substitution of 25% milk protein by modified soy protein resulted in a slightly greater gain and decreased incidence of scours. Differences in performance between pigs fed 50% modified soy protein and 50% soy flour protein diets were not significant. Up to 75% milk protein replaced by modified soy protein did not show significant differences. Pigs on all milk protein diets exhibited a greater incidence of scours.

There was no advantage from supplementing the milk replacer with fresh or freeze-dried cow colostrum. Slightly depressed growth and moderate scour could be seen as pigs were shifted from liquid diets to dry diets at 7 days of age, but later a compensatory growth resulted in equal weight gains for all treatments at 3 weeks of age.

This study indicates the feasibility of rearing newborn pigs on dry diets from 7 days of age, group-feeding in a conventional nursery with similar performance as individually fed pigs receiving a liquid diet. It also shows that soy products are potentially an economical protein source for pig milk replacers.