Nutritional Approaches for Improving Neonatal Piglet Performance: Is There a Place for Liquid Diets in Commercial Production?* - Review -

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ABSTRACT : This report includes an extensive bibliography of research articles investigating various facets of rearing neonatal piglets using liquid diets, and includes historical publications dating back to the 1940's. However, in order to provide concise and timely focus for application in modern swine production, only a selected number of recent findings are reviewed in detail. Collectively, the data presented illustrate that growth of piglets fed liquid diets can greatly exceed that of littermates fed dry diets and can even exceed growth rates of sow-reared controls (by up to 160%). The central questions that remain unanswered are: 1) Can this improved performance be obtained routinely and economically under applied farm conditions? and if so, 2) Does improved growth during the early-weaning period translate into improved net economic returns overall? Unfortunately, due to the current practical management constraints related to liquid-diet feeding (i.e., lack of an easy-to-manage feed delivery system), limited data are available which examine the efficacy of liquid-diet feeding under practical, commercial farm conditions.

(**Key Words:** Neonatal Pig, Liquid Diets, Milk Replacer, Early Weaning)

INTRODUCTION

Average weaning age of piglets in the U.S. has progressively declined over the last 20 years owing to the continued pressure on the swine industry to improve the efficiency of pork production. Reducing age at weaning has the potential of improving efficiency insofar as the farrowing interval of sows is reduced (increasing pigs/sow/year) and disease transfer from sow to piglet is reduced (via segregated early weaning), thereby increasing growth rate and efficiency in subsequent growth phases. In this context, an exciting opportunity for the feeding of manufactured liquid-diets is emerging as a means of maintaining optimal feed intake and reducing the stress on young pigs as they are removed from the dam. A second opportunity for liquid-diet feeding involves supplementation during lactation. Indeed, Azain et al. (1996) have documented increased weaning weights in supplemented litters especially during hot summer months when sow feed intake and milk production are reduced. As evidenced by the success of liquid diets developed for veal calves and formulas for human infants, substantial technology related to diet formulation and manufacturing is already established. However, similar large-scale adoption by the swine industry has not occurred to date but represents a potentially viable possibility.

THE CHALLENGE AND THE OPPORTUNITY

Traditional weanling-pig management is accompanied by many environmental, behavioral, immunological and nutritional stressors, which are exacerbated in very young pigs (i.e., 10-14 d), and when other disease insults (e.g. PRRS) are present. Symptoms of postweaning stress include reduced feed intake, diarrhea, and atrophy of small intestinal villi (resulting in a lower digestive and absorptive capacity) and ultimately result in reduced weight gain. Reduced growth performance during the early postweaning growth phase directly leads to an increase in days to reach market weight, and may also contribute to increased susceptibility to health challenges. Also, nutrient constraints in the early growth phases may result in reduced capacity for lean growth in subsequent phases of growth. Nutritional stress ensues when the piglet is forced to abruptly change from hourly consumption of moderate amounts of sow's milk (containing water soluble, highly-digestible nutrients) to a

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dry weaning diet of contrasting temperature, smell, taste, texture, composition, and digestibility. Thus, poor feed intake and digestive disorders (malabsorption and diarrhea) together detract from piglet growth (Zijlstra, 1996). Development of dry starter diets with improved palatability and digestibility have reduced, but not eliminated the problem. Consequently, the feeding of manufactured liquid diets during an early-weaning transition period offers real potential for enhancing nutrient intake and thus growth of the young pig.

RESEARCH REVIEW

From a historical perspective, early investigations into the "artificial rearing" of piglets using liquid diets date back to the 1940's and continued through the late 60's and 1970's with the seminal work of Lecce and co-workers at North Carolina State University and Braude, Newport & co-workers at Reading. Due in part to the appeal of the piglet model for studies related to human infant nutrition (Reeds & Odle, 1996), an increasing number of publications also have occurred in recent years. From this body of literature, six experiments were selected for detailed review based upon the relevance of their findings for application in present-day production agriculture.

Study 1: What is the growth potential of the runt pig? ⟨*Benevenga, N. J., F. R. Greer and T. D. Crenshaw. 1990. University of Wisconsin Swine Day Report pp 4-6.*⟩

Methods. Normal birth-weight pigs (n=12) were given *ad libitum* access to a reconstituted (20% solids) cow-milk-protein based diet (24% protein, 18% fat). Piglets were individually penned in metabolic cages. Fresh liquid diet was prepared and delivered using a simple feeding system wherein a plastic reservoir supplied the liquid diet to a rubber nipple via gravity.

Results. Congruent with research reports from 20 years earlier (Braude et al., 1970a; Lecce, 1969), researchers at Wisconsin demonstrated that the growth potential of piglets (during day 4 to day 10 of life) fed manufactured liquid diets can exceed that of sow-suckled littermates by 35% (figure 1). Dry matter intake increased linearly over the 6 days of study and the average feed efficiency (gain/feed) exceeded 1.4.

Study 2: Limitations of sow milk yield on baby pig growth. ⟨*Harrell, R. J., M. J. Thomas and R. D. Boyd. 1993. In: Proc. 1993. Cornell Nutrition Conference, Ithaca, NY.*⟩

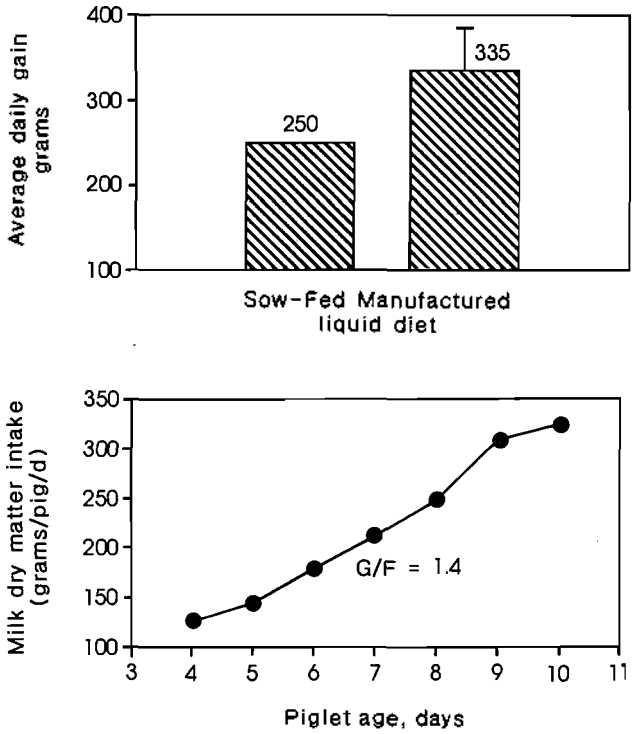
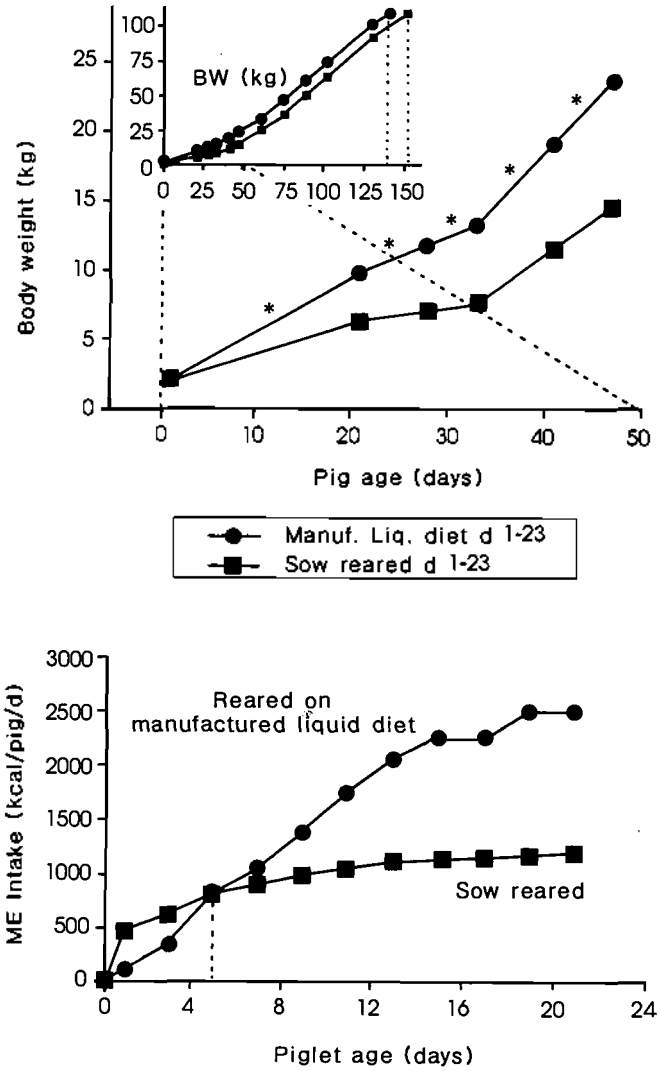


Figure 1. Daily dry matter intake (lower panel) and average daily gain (upper panel) of piglets given *ad libitum* access to milk replacer compared to sow-suckled controls. Gain to feed ratio averaged 1.4 in milk-replacer fed piglets. (*Adapted from Benevenga et al., 1990.*)

Methods. Artificially reared pigs were removed from the dam at 2-3 days of age and gradually acclimated to a manufactured liquid diet (29.3% protein, 22.5% fat) reconstituted to 15% solids. Pigs were housed individually and fed *ad libitum* via a semi-automatic dispenser to which fresh liquid diet was added several times per day. Both the artificially reared and the largest sow-reared controls (n = 8/group) were then weaned onto a common dry diet at 23 days of age. Subsequently, animals were individually penned and fed diets that exceeded NRC requirements for each phase of growth until a market weight of 110 kg was attained.

Results. Superior performance of neonatal pigs reared on manufactured liquid diets (figure 2) demonstrated that sow-milk production may limit piglet growth as soon as one week into lactation. Furthermore, results documented that the acceleration of growth rate continued until pigs were 47 days of age, well after the liquid-diet feeding was discontinued (i.e., after day 23). Thus, pigs fed manufactured liquid diets reached market weight (110 kg) ten days earlier than the best sow-reared controls, and carcass characteristics were unaffected. These data corroborate other studies (Mahan et al., 1998, Mahan &



* indicates increased rate of gain compared of milk-replacer fed compared with sow-nursed controls, $p < .05$.

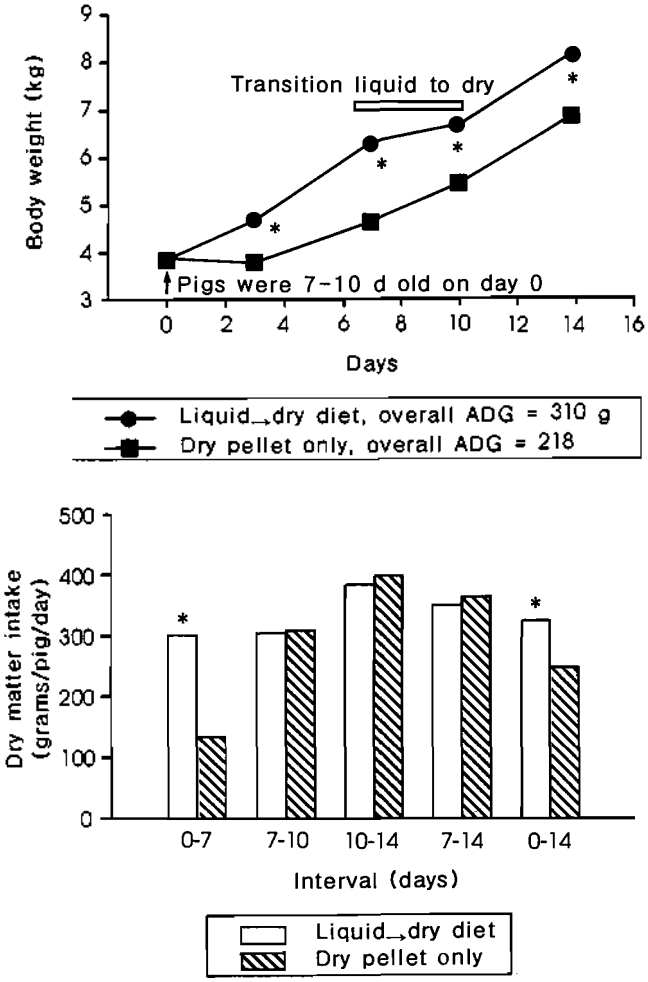
Figure 2. Lower panel shows daily metabolizable energy intake of piglets offered milk-replacer *ad libitum* (circles) compared with estimated intakes of pigs nursing the sow (squares). Metabolizable energy intake of milk-replacer fed pigs exceeded that of sow-suckled pigs after one week of age. Upper panel shows the corresponding accumulative growth curves of the piglets in each group. (*Adapted from Harrell et al., 1993.*)

Lepine, 1991; Tokach et al., 1992) showing that accelerated growth in early life can result in more rapid attainment of market weight.

Study 3: University of Georgia. (*Azain, M. J. 1997. Proceedings of the Carolina Swine Nutrition Conference. pp 1-14.*)

Methods. Early-weaned pigs were removed from the sow at 7-10 days of age. Negative controls were fed a dry pelletted diet (n=36 pigs) throughout the 14 day study. Using Kane feeders, littermates (n=18) were fed liquid diets (Milk Specialties formulation) for the first seven days, transitioned to the dry pellet over days 7-10 and then fed pellets only for days 10-14. Final weights were collected on day 38.

Results. Over the first week (figure 3), piglets fed liquid diets consumed more than twice as much dry matter as littermates weaned onto a dry pelletted diet and correspondingly, weight gains were increased by a similar



* indicates difference between liquid and dry feeding regimens, $p < .05$.

Figure 3. Daily dry matter intake (lower panel) and accumulative growth curves (upper panel) of pigs weaned at 7-10 days of age on to milk-replacer for one week followed by a 3-day transition to dry feed (open bars and filled circles, respectively) compared with control pigs weaned directly onto a dry pelletted diet (hatched bars and filled squares, respectively). (*Adapted from Azain, 1997.*)

magnitude. As liquid-fed pigs were transitioned to dry feed (over test days 7-10), intake and growth rates were similar to controls, but body weights remained significantly higher throughout the 14-day study. When pigs were 6-7 weeks of age, those that had been fed liquid diets during the weaning transition still tended ($p < 0.2$) to be heavier by about 2 kg/pig (data not shown).

Study 4: Effect of feeding a milk replacer to early-weaned pigs on growth, body composition, and small intestinal morphology compared with suckled littermates. ***〈Zijlstra, R. T., K. -Y. Whang, R. A. Easter and J. Odle. 1996. J. Anim. Sci. 74: 2948-2959.〉*** **Experiment 1.**

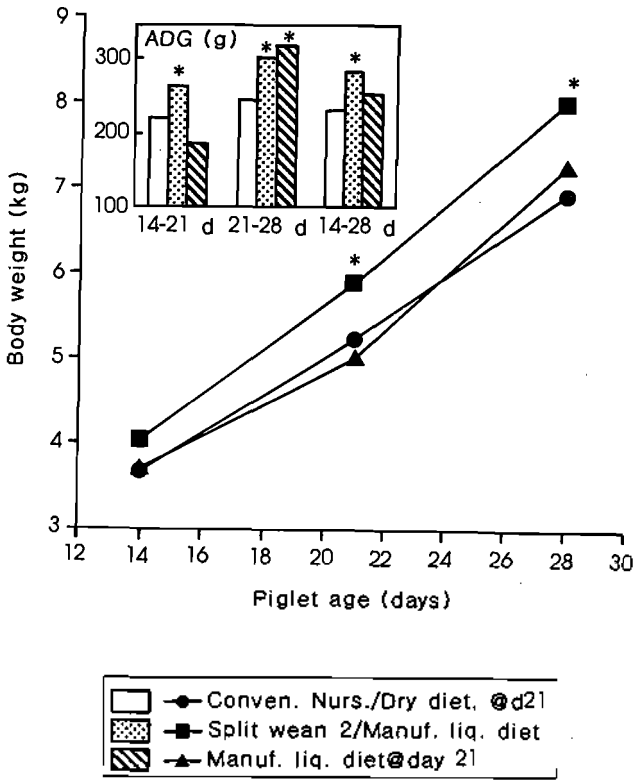
Methods. Pigs (N = 180) from 18 litters were used to examine the utility of liquid diet feeding of young pigs using a specialized nursery building marketed by Intensive Care Nursery, Inc. (Colfax, IL). Pigs were given *ad libitum* access to either liquid or dry diets. Liquid diets (Milk Specialties formulation) were based upon cow-milk proteins and were fed within the specialized environment of the Nursery-14 building (i.e., heated hovers within a cool room).

Results. Pigs from split-weaned litters (wherein the large pigs from each litter were weaned at 14 days of age and fed liquid diets and their small littermates remained on the sow) showed superior growth performance compared with litters weaned conventionally at 21 days of age onto a dry starter diet (figure 4).

Study 5: Effect of feeding a milk replacer to early-weaned pigs on growth, body composition, and small intestinal morphology compared with suckled littermates. ***〈Zijlstra, R.T., K.-Y. Whang, R.A. Easter and J. Odle. 1996, J. Anim. Sci. 74: 2948-2959.〉*** **Experiment 2.**

Methods. Forty-eight pigs from four litters were used in this experiment. Litters were standardized to contain 12 pigs for the initial 18 days of life after which littermates were either: a) left on the sow, b) fed a manufactured liquid diet (Milk Specialties formulation; 25% protein; 16% solids) within the Nursery-14 bldg., or c) weaned into a conventional nursery and fed a dry starter diet. Growth was measured over one week after which animals were killed for examination of intestinal morphology and carcass composition.

Results. Experiment 2 again showed that 18-day-old pigs fed a manufactured liquid diet (figure 5) consumed more dry matter (345 vs. 145 g/pig/d) than littermates offered a dry diet and grew almost four times faster. Indeed, growth rates even exceeded sow-suckled



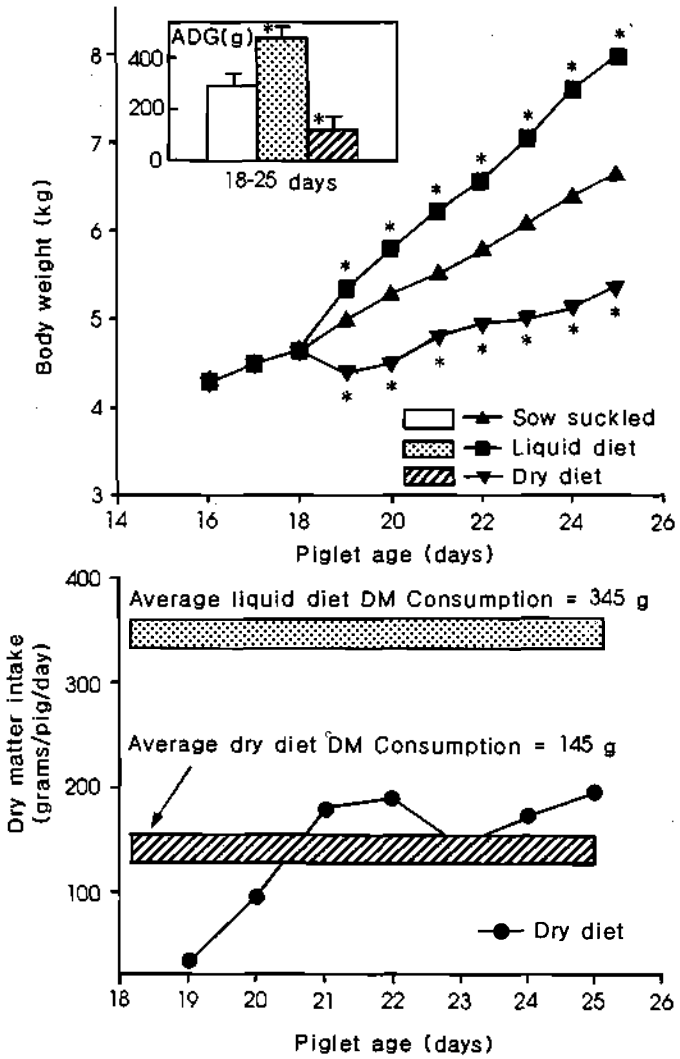
* indicates difference between treatment and control, $p < .05$.

Figure 4. Growth performance of piglets subjected to different weaning regimens. Control pigs (open bar and filled circle) were weaned into a conventional hot nursery at 21 d of age and fed a dry phase I diet. For split-weaned litters (right hatch bar and filled square), the larger half of each litter was weaned at 14 d into a specialized nursery equipped to feed liquid milk replacer, while the smaller half remained on the sow until d 21 at which time they too were moved into the milk-fed nursery for an additional 7 d. The third regimen (left hatch, filled triangle) involved direct weaning at 21 d into the milk-fed nursery for 7 d. (*Adapted from Zijlstra et al., 1996.*)

littermates by over 160%. Furthermore, small intestinal villi were longer in milk-replacer fed pigs and both protein and fat accretion were greater than observed in sow-suckled or conventionally weaned pigs (data not shown).

Study 6: Effect of supplemental pig milk replacer on litter performance: Seasonal variation in response. ***〈Azain, M. J., T. Tomkins, J. S. Sowinski, R. A. Arentson, and D. E. Jewell. 1996. J. Anim. Sci. 74:2195-2202.〉***

Methods. This study utilized 171 litters, half farrowing in cool (avg. = 20.7℃) and half under warm temperatures (avg. = 27.6℃). Litters were randomly distributed among

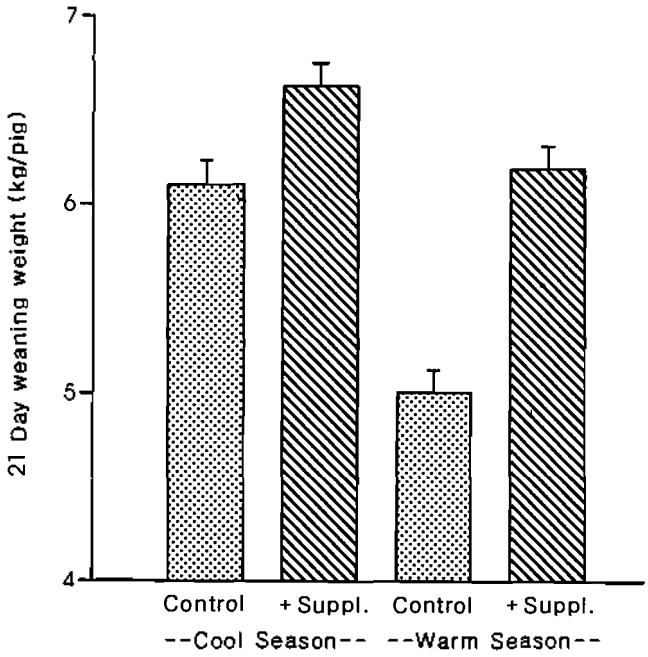


* indicates difference from sow-reared controls, $p < .05$

Figure 5. Daily dry matter intake (lower panel) of pigs weaned at 18 days of age and fed liquid milk replacer or a dry phase I diet for 7 d. Growth performance (upper panel) of pigs weaned on to liquid vs dry diets at 18 d compared with sow-suckled controls. See insert for symbol legend. (*Adapted from Zijlstra et al., 1996.*)

control or milk-replacer treatments. Only litters with greater than 8 live pigs at birth were used. Acidified milk replacer containing cow-milk proteins (Milk Specialties formulation; 25% protein, 13% fat) was reconstituted to 15% solids and offered *ad libitum* within 24 h of farrowing via Kane feeders placed into the farrowing crates.

Results. Supplemental milk replacer during lactation increased 21-day piglet weaning weights (figure 6) by as much as 24%. Supplementation was particularly effective during the warm season when sow feed intake and milk production are decreased (milk replacer × season interaction, $p < .005$). Total milk-replacer dry matter



* indicates difference from respective control, $p < .05$. Supplement × temperature interaction, $p < .05$.

Figure 6. Weaning weights of pigs nursing sows in cool (20.7℃) versus warm (27.6℃) environments, with (crosshatch bars) or without (open bars) supplemental milk replacer. (*Adapted from Azain et al., 1996.*)

consumption by piglets averaged 0.44 and 1.40 kg/d in cool and warm environments, respectively.

CONCLUDING REMARKS

Collectively, these data, from a diverse group of experimental designs, methods, and diet formulation convincingly illustrate that piglet growth can be greatly accelerated by the feeding of manufactured liquid diets. Widespread adaptation by the swine industry awaits development of a robust liquid feed delivery system and documentation of return on investment under practical field conditions. Accelerated growth rates, reduced days to market, reduced mortality and improved sow body condition are among the potential economic attributes of this technology, which must be evaluated against special equipment costs and the relative cost of liquid-diet ingredients. Regarding the later, research with alternative protein, carbohydrate and fat sources could lead to further improvements in potential economic returns.

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