ABSTRACT

RUSSELL, SUMMER MACKENZIE. The Efficacy of Nipple Drinkers and a Direct-Fed Microbial on the Performance of Large White Commercial Turkeys. (Under the direction of Dr. Jesse L. Grimes.)

Concern over the use of dietary antibiotics has encouraged the poultry industry to find alternatives. PrimaLac® (Star Labs, Clarksdale, MO) is a direct-fed microbial (DFM) that contains viable bacterial cultures *Lactobacillus*/*Streptococcus* sp. In the turkey industry, the use of nipple drinkers is being examined to enhance growing conditions. The objective of this study was to test the efficacy of nipple drinkers and DFM on turkey performance. A 2 by 6 factorial design was used (6 drinker types & 2 feed treatments): 1) control Plasson Minibell (T_1), 2) Plasson Easy Start (T_2), 3) Lubing Traditional (T_3), 4) Lubing Easy Line (T_4), 5) ValCo Turkey Drinker (T_5), and 6) Ziggity, Big-Z Activator (T_6). In trial one, T_1 and T_3 drinkers were changed to T_1 at 6 weeks, T_6 changed at 7 weeks, and T_2 changed at 8 weeks. T_5 and T_4 drinkers remained in use until market. In trial two – experiment 2, all drinkers remained in use until market except $T_{3,}$ changed to T_1 at 6 weeks. T_6 was also changed to T_1 at 14 weeks due to severe water restriction. Typical turkey diets were formulated with and without PrimaLac®.

In trial 1, BUTA (Lewisburg, WV) Large White male poults (18/pen) were placed in 48 pens (8 pens/treatment) on day of hatch and were reared to 20 weeks. Feed consumption (by pen) and body weight (BW) were determined at 3, 5-8, 10, 12, 15 and 20 weeks. In trial 2 – experiment 1, 1440 hen poults of (30/pen) 2 strains, A & B, were reared to 3 weeks. Partitions were used to increase brooding density and were removed for the grow-out period. In trial 2 – experiment 2; similar methods were used. 1440 Large White Hybrid Converter® (Kitchener ON, Canada) were reared to 18 weeks. Feed

consumption, by pen, and BW were measured at 1, 3, 5-6, 8, 10, 12, 14, 16, and 18 weeks. Feed conversion (FC) was calculated at each measurement for each trial. Data were analyzed in each trial using the General Linear Model procedure of SAS, Inc., using the LS Means procedure to separate treatment means ($p \leq 0.05$). There were no feed by drinker type interactions in any trial.

In trial 1, 6 week BW of the birds on T_2 and T_6 was less than those on T_1. Differences in BW due to drinker type remained through 10 weeks. Twelve week BW of T_2, T_4, and T_6 birds were no longer different from the control. By 15 weeks, BW of birds reared on T_3 remained less than the birds reared on T_1 with body weight for T_5 intermediate. There were no differences in feed conversion among drinker types until 20 weeks. FC was improved for birds fed DFM for the duration of the trial, and BW was greater for these birds through 12 weeks.

In trial 2 – experiment 1, there was mortality by both strain and drinker type with most mortality seen in strain A and T_4. In trial 2 – experiment 2, BW of birds reared on T_1 and T_5 was higher than birds on T_2 and T_6 with T_4 being intermediate at 6 weeks. T_3 yielded lower BW at 6 weeks than did all other drinker types. By 16 weeks, there were no longer any differences in BW by drinker type. BW was higher for birds fed DFM and cumulative FC was improved through 8 weeks. The results of these trials show that some nipple drinker systems are effective through the brooding period for turkeys with some systems being capable of carrying birds through to market age. The direct-fed microbial used herein is a viable alternative candidate to dietary antibiotics for rearing turkeys.

The Efficacy of Nipple Drinkers and a Direct-Fed Microbial on the Performance of Large White Commercial Turkeys

by

Summer MacKenzie Russell

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APPROVED BY:

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Chair of Advisory Committee	Member
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Member	Member

BIOGRAPHY

Summer MacKenzie Russell is the daughter of James and Ann Russell. She was born in Durham, North Carolina on September 22, 1982. She was raised in White Oak, NC on a large livestock and poultry farm. In 2000, she graduated from East Bladen High School. While in high school, she completed her entire college freshman year's credit hours at Bladen Community College through a program sponsored by her high school. This allowed her to begin at North Carolina State University as a sophomore. She received two Bachelor of Science degrees in Animal Science and Poultry Science from North Carolina State University in 2004. Immediately after graduation, she entered graduate school to pursue her Master of Science in Poultry Science under the direction of Dr. Jesse Grimes.

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Introduction

In today's society, there is an ever-increasing demand for quality animal protein products. This increased demand has also brought the demand for the healthiest and safest product possible. This puts tremendous pressure on animal industries to produce a healthy, yet cost-effective product. The poultry industry not only accounts for the largest portion of the food animal industry, but it has emerged as the leader in animal agriculture and a model industry in efficiency, safety, and cost-effectiveness. The poultry industry takes advantage of all possible areas that can be improved for more efficient production and depends on rapid adoption of technology to stay ahead of competing countries (Michel et al., 1998). The United States broiler industry is said to be the most technologically advanced in the world (Michel et al., 1998). In today's global market, the country with the competitive edge will be the most technologically advanced with the lowest cost production (Michel et al., 1998).

The turkey industry has recently expressed an interest in nipple drinker technology as a way to improve production efficiency. In the late 1980's and early 1990's, nipple drinkers became the predominant drinker of the broiler industry, replacing open-water systems like the bell-type drinker and the trough waterer. For broilers, nipple drinkers are considered the most effective watering system. There are conflicting reports as to just how much advantage nipple drinkers can deliver, but there is a general consensus that the advantages, most often, out-weigh the disadvantages. When compared to conventional open-watering systems, nipple drinkers generally cause slightly reduced body weights that can be considered comparable at best. However, birds raised on nipple drinkers almost always show improved feed conversion and lower mortality. According to Wabeck et al. (1994), nipple drinkers deliver fresh, less contaminated drinking water, resulting in healthier birds. Wabeck et al. (1994) also note that with nipple drinker use, reduce water spillage, which allows for drier litter. Wet litter resulting from water wastage, can contribute to an increase in litter ammonia levels, increased incidence of disease, and even foot problems in birds (Michel et al., 1998). Presumably, drier litter and reduced pathogen load can improve the overall performance of the bird because the production environment will be more sanitary. Broiler flocks, for the preceding reasons, are said to be more profitable when reared on nipple drinkers (Lee and Zimmerman, 1987).

Being a closed-water system, the drinking water delivered by nipple drinkers is inherently cleaner, as is the drinker itself. Another advantage of nipple drinkers is the reduction in labor requirements. Unlike bell-type drinkers, nipple drinkers do not have to be cleaned which saves growers time and labor costs (May et al., 1997). With this advantage, there is a disadvantage, when using nipple drinkers. Nipple drinkers require more intense management than do open-water systems, and the success of their implementation is dependent on proper management (Wabeck et al., 1994).

The poultry industry is focused on creating the healthiest living environment possible in conjunction with reduced reliance on antibiotics (Watkins, 2002). While one component of this healthy living environment is improving drinking water quality (Watkins, 2002), the industry's need to find alternatives to antibiotics to enhance health and promote growth is at the forefront of industry developments. The use of antibiotics to treat disease has never been questioned as long as the diagnosis is correct, but the use of antibiotics as growth promoters is currently in question (Joerger, 2003). It has been reported that 77% of consumers think that meat contains harmful residues and that this was of extreme concern (Donoghue, 2003). Popular media supports these and other false perceptions about food. This is evident in consumer perception of hormone use in animal production. Consumers are also reported to believe that hormones in meat are a problem even though hormones are not approved for use in poultry production and are extremely closely monitored in all animal production. Similar trends in consumer perception can be seen with antibiotic use by the food-animal industry. Any drug approved by the FDA is not only strictly regulated, but must undergo a rigorous approval process with the FDA before it is legal for use (Donoghue, 2003). In the United States, food safety is ensured by FDA and USDA regulations and regulatory monitoring programs (Donoghue, 2003).

With increased scrutiny and public concern, many countries in the European Union have banned the use of subtherapeutic antibiotics as growth promoters. In the United States resulting agencies are looking closely at how antibiotics are used and are considering banning specific antibiotics in animal production for both therapeutic and growth promoting purposes. There is a great need in the poultry industry to find alternatives to antibiotics. Public health concerns about antimicrobial resistance have forced closer examination of alternatives to antibiotics both on the therapeutic and subtherapeutic level. There are several current alternatives being explored including direct fed microbials or probiotics, prebiotics, oligosaccharides, feed conversion enhancing enzymes, and organic acids. Probiotics and other competitive exclusion supplements are already in use and the addition of enzymes can work well when used in combination with the correct feed ingredients (Joerger, 2003). In addition, antibody treatments have been developed for enteric problems, cytokines can be used to enhance immune function and promote growth in broilers, and bacteriocins, antimicrobial peptides, as well as bacteriophages have therapeutics potential (Joerger, 2003).

The purpose of these studies was to examine the effectiveness of nipples drinkers and the direct-fed microbial PrimaLac® in production and evaluate their affect on the performance of commercial turkeys. Because there is very little data supporting nipple drinker research with turkeys, the scope of the following review is limited to related broiler data on the efficacy of nipple drinkers in production and the effect of nipple drinkers on specific production parameters.

Water Quality

As modern broilers have been selected for increased performance efficiency, they have become increasingly less tolerant to many stressors commonly encountered in modern production such as reduced water quality (Watkins, 2002). The effects of water quality can be indicated by poor flock performance, increased feed wastage, decreased weight gains, and/or flock health problems (Watkins, 2000). Water quality should be evaluated regularly. Compounds in water can affect water's palatability and reduce consumption (Counotte, 2000). Water quality can be evaluated in several ways: bacterial load, naturally occurring minerals, as well as physical and chemical factors (Carter, 1991).

Closed water lines are thought to be more sanitary. Regularly tested closed water lines showed that bacterial contamination is not only present, but common (Watkins, 2002). High bacterial counts can negatively affect performance (Carter, 1991), but regular sanitation of closed water lines can combat this problem. Water pH can affect digestion and be incompatible with medications and vaccines given through the water (Carter, 1991). Organic acids are currently being used not only to improve water quality, by reducing bacterial load, but are also being studied as an alternative to antibiotic growth promoters (Giesen, 2005). A commonly encountered water quality issue is hard water. Minerals at normal levels are generally not a problem, but out of balance, whether alone or in combination (Carter, 1991), these minerals can negatively affect medication and the efficacy of water delivered vaccines (Counotte, 2000).

Water Consumption

Water is arguably the most important of all macronutrients, but often the most overlooked; it is important to all body processes. It serves to soften feed in the crop, aid in digestion processes, carry food through the digestive tract, and is a component of blood and lymph (Watkins, 2000). An animal can loose up to 40% of its body weight from feed deprivation and survive, but if an animal looses 20% of its body water, it will die (Tabler, 2003). Understanding water's importance is essential to successfully raising any animal. Knowledge about an animal or group of animal's water consumption can even be a diagnostic tool (Ross and Hurnik, 1983). Water consumption is affected by age, body weight, body temperature, disease status, and feed consumption (Tabler, 2003) and knowing consumption patterns of a group of animals can allow a producer to assess that group's health and well-being.

Poultry, in particular, have special issues when it comes to water and its consumption because of the way in which they consume it. Birds drink by taking water from a pool, raising their head, and letting the water run down their esophagus (May et al., 1997). For the bird, getting water from a nipple, a higher point, is not an instinctive behavior and does not allow for the coordination of water intake and breathing. The bird's mechanism of drinking creates a problem when it is panting because drinking must be associated with the reflex action of raising the head causing the birds to have difficulty coordinating drinking and breathing. May et al. (1997) found that lowering nipples during high temps can increase water consumption, but also noted the importance of minimizing panting when possible.

There are many factors that affect water consumption including environmental temperature and humidity, feed consumption, the diets composition and particle size, as well as water additives such as antibiotics and other medications (Pesti et al., 1985). Ross and Hurnik (1983) determined that the watering equipment itself can also affect water consumption. McMasters et al. (1971) observed chicks that were started at day old on nipple drinkers and found that the chicks had no problem finding and using the nipples. At day old, the height of the drinker is critical to the chick's ability to use the nipple (McMasters et al., 1971). The chicks need to reach and use an upward pecking motion to learn to activate the nipple. Conversely, a nipple too low, in this study, delayed the chick's ability to properly use the waterer (McMasters et al., 1971).

Water Consumption during Heat Stress

At no time is water consumption more important than during times of heat stress. Heat stress is defined as temperatures exceeding the highest temperature in the thermoneutral range: temperatures beyond 85°F. Generally, it is thought that water consumption increases with increasing temperature (Donkoh, 1989). This trend is essential to the bird's ability to survive periods of heat stress (May and Lott, 1992). Generally, water consumption is approximately double feed consumption. High temperatures are marked by decreased broiler growth because of decreased feed consumption, increased feed conversion, and increased water consumption (Donkoh, 1989). May and Lott (1992) observed that birds generally eat the most at the lowest cyclic temperature and drink the most at the highest cyclic temperature. Increased water consumption will overall change the feed: water ratio. This change may help maintain feed consumption during high environmental temperatures (May and Lott, 1992).

Different water consumption patterns have been noted between bell-type drinkers and nipple drinkers (May et al., 1997), where anomalies in the aforementioned water consumption patterns were found. On bell-type drinkers, water consumption is proportional to temperature. That is, as temperature increases, water consumption increases. Birds on nipple drinkers had relatively constant consumption until temperature increased. At that point, water consumption of birds on nipple drinkers actually decreased (May et al., 1997). This change in pattern can be attributed to drinker height and high cyclic temperatures (May et al., 1997). The length of the exposure period along with the size of the bird can also influence water consumption of birds on nipple drinkers during high temperatures (May and Lott, 1992). Heat stress mortality can be reduced if broilers have had previous exposure to high environmental temperatures (May and Lott, 1992). This exposure is particularly effective if it occurs early in the bird's life (Lott, 1991).

Chickens are very sensitive to drinking water temperature particularly as it compares to ambient temperature (Harris et al., 1975). The body temperature of the bird will rise if the bird is unable to balance heat production and heat loss (Van Kampen, 1988). Because of the heat absorption properties of water, maintaining water consumption during times of heat stress is crucial to the bird's survival. Drinking water temperature affects the water's ability to absorb heat (Beker and Teeter, 1994). If the water is already above ambient temperature, then its capacity to absorb heat is greatly reduced (Beker and Teeter, 1994). Beker and Teeter (1994) noted that drinking water temperature in heat stress conditions is inversely correlated with feed consumption and growth rate.

During periods of heat stress, birds will reject warmer water if given a choice (Harris et al., 1975). When they do not have an option, they will drink warm water on a limited basis (Harris et al., 1975), but reduced consumption has a profound effect on performance. Heat stress has well documented negative effects on broiler performance including reduced body weights, increased feed conversion, and reduced livability. While water warmer than ambient temperature can depress growth, water cooler than ambient temperature can actually enhance performance (Harris et al., 1975). Providing cooler water, even by a few degrees, is said to increase heat stress survivability (Beker and Teeter, 1994).

Nipple Drinker Effects on Performance

Nipple drinkers have become the predominant drinker of the broiler industry replacing the bell-type drinker in most instances. There are several advantages to nipple drinkers which generally relate to the system being closed. These drinkers are thought to produce healthier flocks because they are capable of delivering clean, uncontaminated drinking water (Wabeck et al., 1994). A closed-watering system does not have to be cleaned by the grower which in turn reduces labor costs (Lott et al., 2001). Nipple drinkers decrease water spillage and subsequent wastage, resulting in drier litter which reduces the pathogen load of the litter, and improve the sanitation of the growing environment (Branton et al., 2001). Several authors report reduced condemnation of birds raised on nipple drinkers at processing compared to open-watering systems (Wabeck et al., 1994; Carpenter et al., 1990; Lott et al., 2001; Vest, 1986; Branton et al., 2001). With these advantages, broiler flocks raised on nipple drinkers are more profitable than those raised on traditional open-watering systems (Lee and Zimmerman, 1987).

There are conflicting reports as to how nipple drinkers affect broiler performance. There is overwhelming evidence published results indicating body weights achieved by birds raised on nipple drinkers are lower than body weights of those birds raised on traditional open-watering systems such as the bell-type drinker or trough (McMasters et al., 1971; Wabeck et al., 1994; Andrews and Harris, 1975; Lee and Zimmerman, 1987; Carpenter et al., 1990; Lot et al., 2001). Conversely, anecdotal evidence from field producers showed that broilers raised on nipple drinkers had similar body weights, improved feed conversion, and lower condemnation rates as compared to open-watering systems (Brown et al., 1995). Lee and Zimmerman (1987) concluded that the benefits of nipple drinkers are enough to outweigh the decreased body weight yielded by nipple drinkers. It is generally accepted that birds raised on nipple drinkers have improved feed conversion (Wabeck et al., 1994; Carpenter et al., 1990; Brown et al., 1995).

Other factors that affect how well the bird will perform when raised on nipple drinkers including the season or time of year, the nipple: bird ratio, as well as how the drinker system is managed. Birds raised on bell drinkers have significantly lower body weights in summer and winter when temperatures are at their extremes (Wabeck et al., 1994). Body weights were also found to be significantly less for birds raised on nipple drinkers in the summer (Wabeck et al., 1994). The best overall performance, regardless of drinker, can be expected when temperatures are milder in the spring and fall (Wabeck et al., 1994). Within the time of year, Na-Lampang and Craig (1990) showed that birds use the nipples at relatively similar times of day despite season or the number of birds per nipple. They found that birds use drinkers less in the warmer afternoon temperatures and more in the cooler morning and evening hours.

The bird: nipple ratio can play a major role in determining how birds will perform when raised on nipple drinkers. Too few birds per nipple impairs the groups ability to quickly find and learn to use the drinker properly while too many birds per nipple can reduce performance because of competition for water. Dodgen and Harris (1971) found 20 birds per nipple to be optimum for broiler performance up to 4 weeks of age while 15 and 25 birds per nipple showed decreased body weights. Conversely, McMasters et al. (1971) found that body weight increased with increasing numbers of nipples. A bird to nipple ratio in this study of 13:1 showed lower growth (McMasters et al., 1971). There was a positive growth response when the ratio was decreased to 8:1 or 2.5:1, but no difference in actual water consumption was observed at these ratios (McMasters et al., 1971).

Nipple Drinker Management

While there are several advantages to using closed-watering systems, they do require different and often more intensive management than do traditional open-watering systems. The producer must be more knowledgeable to manage such systems (Tabler, 2003). There are a few general management strategies that are required for nipple drinkers. Water pressure should be increased as birds age, and air should be cleared from water lines periodically to prevent accumulation of air in the lines (Vest, 1986). Similarly, the flow rate of the nipple itself must be considered before using a nipple drinker system. High flow rate nipples can provide up to six times the amount of water of a low flow rate nipple, which can reduce the amount of time spent by the bird meeting its water requirement (Carpenter et al., 1992). Also, high flow rate nipples have been found to be beneficial to heavier birds like large male broilers while low flow rate nipples are not believed to provide enough water to larger birds (Carpenter et al., 1992).

Height of the drinker and the providing of supplemental waterers are arguably the most important things that must be managed in closed-watering systems. The height of the drinker has a significant effect on water consumption and thus performance (Branton et al., 2001). Birds naturally have a hard time drinking from a higher point and lowering the height of the nipple can result in faster growth and improved feed conversion (Branton et al., 2001). Generally, the height of the line should be adjusted for the smallest bird relative to the height of the bird. For optimum performance, the bird should have to stretch their neck and drink at the end of their beak, but they should not have to lift their breast to do so; this can require almost daily adjustment (Tabler, 2003). May et al. (1997) found that water consumption was significantly affected by drinker height relative to the height of the bird. Water consumption was greatest from bell-type drinkers, intermediate from low height nipples (nipples from which the bird had to stoop to drink), and the lowest consumption was observed from high height nipples (nipples from which the bird had to stretch, lifting the breast, to drink) (May et al., 1997). Feed conversion also increases with increasing nipple height (Lott et al., 2001). The further the bird has to extend to get water, the more unfavorable the effect will be on broiler performance (Lott et al., 2001).

The use of supplemental drinkers to provide added water accessibility for chicks has been studied with conflicting results. Andrews and Harris (1975) found that the use of jug drinkers for the first two weeks yielded heavier birds. Similarly, Carpenter et al. (1990) found that supplemental waterers were necessary when starting chicks off on nipple waterers, noting a significant difference between broilers with and without access to supplemental waterers. Supplemental waterers improved livability (Carpenter et al., 1990). Conversely, McMasters et al. (1971) found that chicks had no problem finding and using nipple drinkers at day old and that supplemental drinkers were not necessary. The labor used to fill and clean such drinkers could be eliminated if the supplemental drinkers are not necessary (McMasters et al., 1971). If supplemental drinkers are not used, nipple height must be closely monitored because nipples placed too low or too high can delay chick adoption and adaptation (McMasters et al., 1971).

Turkey Data

There are very limited data on the use of nipple drinkers in turkey production. As with broilers, providing good quality drinking water for turkeys is often an overlooked and underestimated component of the production environment. Turkeys need an optimum water supply to achieve their full genetic potential. With the constant effort to improve production efficiency, the turkey industry is currently considerting nipple drinkers as a possible alternative to traditional open drinker systems. Currently, there is no economic advantage to utilizing open-watering systems (Hulet, 1999), but it is thought that they are the only drinker technology that can consistently deliver better body weights and average daily gains, especially in summer-like growing conditions.

There are several drinker companies working to develop a nipple drinker that is compatible with turkeys and will improve production efficiency. Because of the inherent differences between broilers and turkeys, there are several modifications that are being made to adapt traditional nipple drinkers for use with turkeys (Hulet, 1999). Turkeys require an open reservoir of water from which to drink because they do not coordinate drinking from a traditional broiler nipple at a high enough level to provide adequate amounts of water to sustain growth even with high flow nipples. Drinkers being modified for use with turkeys all have an open water modification, usually providing water in a cup beneath the nipple. These cups are refilled simply by the action of the bird using the drinker rather than the bird having to manually trigger the nipple as is seen with traditional broiler nipples.

In a research trial by Hulet (1999), there were significant differences in body weight between nipples and Bell-type drinkers by 4 weeks of age. Hulet (1999) did note that equivalent weights could be achieved in hens up to 10 weeks of age. In field trial data, birds raised on nipple drinkers were lighter at 5-6 weeks, but weights equalized by 10 and 12 weeks (Rives unpublished data 2001). These birds experienced some compensatory growth after the birds were switched from nipple drinkers for brooding to bell drinkers for the grow-out period. Hulet (1999) also found that water consumption was significantly lower for turkeys on nipple drinkers than those on bell drinkers by 6 weeks of age (Hulet, 1999). High flow rate nipples increased water consumption by making water more available, but the differences were not eliminated (Hulet, 1999).

Additionally, bell drinkers yielded a higher ratio of water consumption per unit feed than nipple drinkers (Hulet, 1999). As seen in broiler production, there was increased cake and litter moisture beneath bell drinkers as compared to the nipple drinkers (Hulet, 1999).

Successful use of the nipple drinker in turkey production requires more intense and careful management (Hulet, 1999). This is particularly true when common trimming errors inhibit the birds ability to fully utilize their beak in the period immediately following the procedure (Hulet, 1999). Rives (2001) noted the advantages of nipple drinkers compared to bell drinkers such as improved flock health and reduced labor for cleaning. Nipple drinkers with high flow rates can be effective in turkey production through the brooding period or up to 10 weeks of age, but not through to market (Hulet, 1999). Currently, a combination of nipple drinkers for the brooding period and bell drinkers for the grow-out period may be optimum (Rives, 2001). More modifications to nipple design are necessary for increased effectiveness. There is a great need for more research in this area to draw definitive conclusions about the efficacy of nipple drinkers in turkey production.

History of Growth Promoters

Antibiotics have been used as growth promoters for more than 50 years in the United States and elsewhere (Dibner and Richards, 2005). In the 1940's, the poultry industry in the United States experienced its first technical "boom" due to development in genetics, nutrition, housing, and marketing systems (Jones and Ricke, 2003). Developments in nutrition brought increased demand for animal protein as the industry became increasingly aware of the importance of certain nutritional factors. In the late 1940's, the industry experienced a shortage in animal protein substituted plant protein.

Scientists noted that plant protein sources lacked an “animal protein factor”; later determined to be vitamin B_{12} (Jones and Ricke, 2003). Moore et al. (1946) were the first to show that putting antibiotics in chicken feed could induce increased weight gain. Antibiotics were approved by the FDA for use in animal feeds without veterinary prescription in 1951 (Jones and Ricke, 2003).

Since their inception, antibiotic use as growth promoters have not been without controversy. Recently, that controversy has been at the forefront of the public concern that is driving current regulatory actions to reduce or eliminate the use of antibiotics as growth promoters. Of principle concern is the issue of antibiotic resistance in human medicine, and the role antibiotic use in animal agriculture may or may not play in that resistance. Decreased effectiveness of drugs due to resistance, was reported as early as 1958 (Dibner and Richards, 2005). The first investigation into antimicrobial use in animals affecting resistance in human pathogens was in a 1969 report to British parliament (Swan, 1969). In the 1980’s when a number of pathogenic bacteria were found to be resistant to several antibiotics (Aarestrup, 2003). Despite this concern, the relationship between antimicrobial use in animal production and antibiotic resistant infections in humans has never been proven and is currently the subject of intense debate (Alpharma, 2004).

There is no doubt that antibiotic resistance is on the rise and is largely attributed to overuse in human medicines (Bywater, 2005). Still, there is growing concern that antibiotic use in animal production that could potentially transfer to human pathogen populations (Bywater, 2005). There is relatively little evidence that antibiotic growth promoters pose a threat to human health (Cervantes, 2004); Bywater (2005) noted that the total animal contribution to human resistance problems is less than 4%. Zoonotic bacteria pose the most obvious threat because a resistant population could be passed from animal hosts to human hosts thus passing a resistant infection to humans (Bywater, 2005). Bywater (2005) also suggests that resistance in isolated microbial populations, with little or no exposure to antibiotics from human or animal use, is nearly as high as in exposed populations suggesting that bacterial epidemiology of resistance may be misunderstood.

Regardless of the cause, bacteria are becoming increasingly resistant to conventional antimicrobials, and this has lead many countries to ban to use of antimicrobials as growth promoters. The European Union has banned the use of antibiotic growth promoters completely, and antibiotics in animal production are to be phased out by 2006. Sweden was the first to stop using antimicrobials for growth promoters in 1986 (Aarestrup, 2003). The league of nations in the European Union followed with a ban in September 1999. This ban started with specific antibiotics, but by December 1999 the European Union had voluntarily stopped the use of all antimicrobials as growth promoters (Dibner and Richards, 2005). Anticoccidials remained in use, but are scheduled to be discontinued in 2006 (Cervantes, 2004). The use of antibiotics in the European Union is limited strictly to therapeutic uses only. Public pressure in the United States is driving the removal of all antimicrobials in feed, and their withdrawal seems unavoidable even in the absence of regulations to mandate it. With other countries following the European Union's lead, some export markets have been closed to countries which have not stopped the use of antibiotics as growth promoters.

Since the ban in the European Union, there has been little change in performance of broilers, but this coincides with the increased use of anticoccidials that can have similar effects to antimicrobials. Swine performance has suffered tremendously in average daily gain, down 7g per day, and increased mortality, up 1.7% from 2.2%, since the antimicrobial ban (Dibner and Richards, 2005). European Union's ban on antimicrobials has had negative effects on animal health and welfare as evident by the increase in disease since the ban (Bywater, 2005). While the European Union has reduced its use of antibiotics as growth promoters, therapeutic use has increased, suggesting that subtherapeutic levels served not only to promote growth but also to prevent disease (Bywater, 2005). Removal of antimicrobials from animals feeds has reduced antibiotic resistance in animals in the European Union, but there is no confirming evidence of any human health benefits resulting form the ban (Bywater, 2005).

In the 1950's, birds took 14 weeks to reach market weight; today, it only takes 6 weeks (Solis de los Santos et al., 2005). Antibiotics have played a key role in this remarkable decrease in time to market. Any alternative to antibiotic growth promoters must be able to provide the same level of benefit to the birds as the antibiotic itself. The most obvious characteristics of a growth promoter are its ability to improve feed conversion, increase body weights and gains, and improve overall livability. Improved livability is brought about by immune stimulation by the resident microflora (Dibner and Richards, 2005). Antibiotics prevent the overgrowth of resident gut microflora and the subsequent negative effects such overgrowth can cause as well as providing some defense against enteritis and airsacculitis. Since no single alternative has been identified, the use of ionophores or better management practices may be needed to achieve the same level of improvement. Antimicrobials as growth promoters reduced opportunistic pathogens and subclinical infections, thus improving the overall health of the bird (Dibner and Richards, 2005).

While it is not known with certainty the exact mechanism of action by which antibiotics elicit their effect, it seems to be focused on the interaction between antimicrobials and the gut microorganisms. It is speculated that this interaction and the reduction in gut microbes that follows may be the mechanism of antimicrobial benefit. The gut of a chick or poult is sterile at hatch, but is colonized almost immediately by microflora in the environment. Dibner and Richards (2005) noted that the animal seems to have selection mechanisms in place that aid in proper colonization of the gut. Early exposure to a variety of microbes has great influence on the development and health of the bird, which can have significant impact on performance. While the make-up of the gut microflora is diverse, it is predominated by gram-positive bacteria. In addition, it is said that bacterial cells in the gut out number host cells 10 to1. The bacteria that colonize and naturally occur in the gut compete with their host for nutrients, secrete toxic compounds, and can cause on-going inflammatory immune responses in the gut (McCracken and Gaskins, 1999). Current research focuses on selecting beneficial replacement microbes that are optimal under commercial growing conditions and promoting the growth of these microbes in the gut.

The microflora of the gut can prevent colonization of pathogenic species and provide fermentation byproducts as nutrients to the host (Dibner and Richards, 2005). These fermentation byproducts include such nutrients as short-chain fatty acids, amino acids, B vitamins, and vitamin K. Antibiotics function differently than some of their alternatives in that they not only alter microbial population, they also alter intestinal activity and function as well as the overall metabolism of the animal (Patterson and Burkholder, 2003). Reduction in amino acid catabolites and the antibiotics ability to stop bile breakdown are the primary nutritional mechanism of antibiotic action (Feighner and Dashkevicz, 1987, 1988).

Alternatives to Antibiotic Growth Promoters

It is important to allow the bird time to establish and take advantage of the beneficial microflora before using antibiotics or their alternative which may alter or stop subsequent bacterial growth (Parks et al., 2005). Initially established populations not only ensure proper development of the immune system, but have advantageous protective properties (Parks et al., 2005). Many products and potential candidates for being alternatives to antibiotic growth promoters claim they can manipulate gut microflora including organic acids, probiotics (or direct-fed microbials), prebiotics, bacteriophages, bacteriocins, antibody therapy, trace minerals, enzymes, even herbs and spices.

One such alternative candidate are bacteriophages; viruses capable of infecting and killing bacteria (Huff et al., 2005). Bacteriophages were discovered around the time of antibiotics, but after their discovery, use, research, and development in the field was abandoned with the discovery and success of antibiotics (Huff et al., 2005). Some research continued in Eastern Europe with a renewed interest occurring with the European Union's ban of prophylactic antibiotic use (Huff et al., 2005). Bacteriophages are safe to use to treat bacterial infections because they have no affect on animal or plant cells (Huff et al., 2005). Therapeutic use of bacteriophages has been successful, but results have been inconsistent. Bacteriophage use as an alternative to antibiotics has limitations including high specificity, their ability to act as a vehicle for bacterial genes, uncertainty regarding regulatory acceptance, proprietary problems, fragility of their action, and problems with finding practical modes of administration in production (Huff et al., 2005).

Bacteriophages kill host bacteria by lysis of the cell after replication is complete (Joerger, 2003). One of the main problems with bacteriophages is that the right phage must be used in order for the treatment to be effective (Joerger, 2003). Not all phages do the same thing. It is preferable that the phage's mode of action be lysis of the cell with as little interaction with hose genome as possible (Joerger, 2003). This high specificity is both advantageous and disadvantageous. Their high specificity allows for attack of only certain bacteria making it easy to predict and control their action (Joerger, 2003). However, this narrow host range can make bacteriophages challenging to use effectively. To combat this problem, a cocktail of phages can be used to reduce multiple serotypes of the same bacteria, but this has shown mixed results (Kudva, et al., 1999). These phages get little or no support from the immune system, and if the phage does not attack all of the bacteria present, the bacteria can re-populate to levels higher than they exsisted in prior to the phage therapy (Joerger, 2003). It may be that bacteria grown in laboratory conditions are different than the same bacteria grown in the host's environment. This difference could account for some of the mixed results, both the successes and failures, of phage therapy.

Other alternatives being explored to some degree are serum therapy, bacteriocins, and antimicrobial peptides. Serum therapy has long been considered successful pathogen-specific anti-infective therapy (Bergham et al., 2005). Immunity can be passed from previously challenged animals to naïve animals through serum therapy by administering an immune serum from an immunized animal for prevention or treatment of infectious disease (Bergham et al., 2005). Multiple serotypes of the same bacteria can limit success of passive immunity. Like with bacteriophages, serum therapy had its limitations and research in the area all but stopped prior to WWII with the discovery of antibiotics (Bergham et al., 2005). Because of new developments in production technologies that are capable of providing large quantities of pathogen-specific antibodies in a cost-effective manner, serum therapy has the potential to be a viable antibiotic alternative in the future (Bergham et al., 2005).

Bacteriocins too have also been explored to some degree. These are proteinaceous compounds produced by lactic acid bacteria that can kill bacteria, except the bacteria that produce them (Joerger, 2003). Other bacteria can produce bacteriocins, but lactic acid bacteria are getting the most attention currently because they are generally considered beneficial to human health (Joerger, 2003). Bacteriocins are considered more natural because they are already found in foods (Cleveland et al., 2001). Often, these substances are used in processing as antimicrobials. While their mechanism of action is not well understood, it is thought that like antibiotics, resistance may develop with bacteriocins because they seem to interact with the bacterial membrane which can result in bacteria that are resistant to currently used antibiotics (Carlson et al., 2001).

Antimicrobial peptides are a much smaller group, but they have alternative potential because they seem to occur in most organisms (Joerger, 2003). They interact with negatively charged membranes to elicit effect, but like the bacteriocins, this interaction may lead to resistance. Both antimicrobial peptides and bacteriocins are vulnerable to proteolytic enzymes making bacteriophages the most stable entity of the three (Joerger, 2003).

Added enzymes increase the digestibility of feed ingredients, and some commercially available enzymes have been shown to improve performance by increasing energy utilization, protein digestibility, live weight gain, and improving feed conversion (Sun et al., 2005). Some enzymes serve to bind mycotoxins and detoxify ingredients which also yields increased body weights and feed itake (Sun et al., 2005).

Organic acids have traditionally been used as preservatives to extend the shelf life of foods and are often referred to as fatty acids or volatile fatty acids. These substances can be put directly in human food or used as an acid wash disinfectant during food processing. Organic acids were previously used in animal feeds to reduce fungal growth and are now being looked at for possible bacteriostatic or bacteriocidal effects (Ricke, 2003). Organic acids can suppress pathogenic bacteria by making the intestine acidic and therefore an unfavorable environment for pathogenic bacterial growth (Sun et al., 2005). However, Sun, et al. (2005) suggests that an acidic environment may be favorable for beneficial bacteria. The effectiveness of organic acids as antimicrobials is dependent on the physiological state or condition of the animal as well as the host environment, dependent mostly on pH (Ricke, 2003). Effectiveness of organic acids added to feeds can have several determinants. When added to feed as an antimicrobial, organic acids can interact with protein ingredients such as soybean meal and be converted to a less active form, buffering the acidic effects (Ricke, 2003). Also, the length of time that the feed is stored post-inoculation can reduce the effect of organic acids. Organic acids in feeds, once ingested by the animal, are thought to reduce colonization of pathogenic bacteria in the gut. Conversely, some organic acids never make it to the gut to be effective because they are metabolized prior to reaching the intestines (Ricke, 2003). Microbes can become resistant to the effect of these acids like other antimicrobials whose mode of action affects the membrane.

Mannose based carbohydrates, mannooligosaccharides (MOS), are able to decrease concentrations of enteric pathogens in the gut (Spring et al., 2000), by serving as an alternate binding site for these pathogenic bacteria, preventing their attachment to and colonization in the gut (Parks et al., 2005). Some pathogenic bacteria have fimbriae that are mannose specific which allow these bacteria use to attach to and colonize the gut (Parks et al., 2001). MOS products utilize this by offering an alternative high affinity binding site for the bacteria. When the bacteria bind to MOS, they simply pass out of the tract never having attached to the epithelial surfaces of the gut (Parks et al., 2001). Some MOS products are said to inhibit adherence of pathogenic bacteria by more than 90% (Spring et al., 2000). Because of the way mannanoligosaccharides are manufactured, loosing their sugar properties, these products do not selectively enrich beneficial bacteria and are not considered a prebiotic. These compounds are thought to affect concentrations of gut microflora by absorbing bacteria, thus inhibiting their adherence to small intestinal mucosa (Spring et al., 2000).

Pure mannose is needed in relatively high concentrations in the diet to be effective (Spring et al., 2000). While at high concentrations, mannose is effective at preventing the attachment and subsequent colonization of the gut by pathogenic bacteria, it is not cost effective (Spring et al., 2000). Mannose based products like MOS have been developed, such as Bio-MOS® that have been found to improve body weight and body weight gains (Sun et al., 2005). This is particularly true in *Escherichia coli* challenged birds (Fairchild et al., 2001). Parks et al. (2001) also noted the effects of Bio-MOS®, concluding that MOS can be used as an alternative to antibiotic growth promoters in turkey production. By comparison, Parks et al. (2005) noted that while MOS did elicit a response, alone it may not have a significant effect. This study showed that less antibiotic had more effect on birds that had been fed MOS diets (Parks et al., 2005).

In contrast to mannanoligosaccharides, other sugar derived substances such as fructooligosaccharides retain their sugar properties and are used to selectively enrich beneficial bacteria, making them prebiotics. There are many definitions of what a prebiotic is. Gibson and Roberfroid (1995) define a prebiotic as "a nondigestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon." Most directly, prebiotics are substances that stimulate the growth of beneficial bacteria without stimulating the growth of pathogenic bacteria (Reid and Friendship, 2002). Prebiotics are predominantly fructooligosaccharide (FOS) products and their derivatives (Patterson and Burkholder, 2003). These products stimulate acid production by beneficial bacteria which can inhibit the growth of pathogenic bacteria (Reid and Friendship, 2002). According to Patterson and Burkholder (2003), an ideal prebiotic should selectively enrich certain beneficial bacteria, alter intestinal microbial populations and their activity beneficially, as well as stimulate the host's immune system.

Probiotics (Direct Fed Microbials)

Anything that affects the gastro-intestinal tract also affects feed efficiency. Beneficial bacteria improve feed efficiency by increasing nutrient absorption by the animal (Solis de los Santos et al., 2005). Prebiotics and probiotics seem to be the most viable current alternative candidates to antimicrobial performance enhancers. Prebiotics have been previously described, and as with prebiotics, there are multiple definitions for probiotics. Probiotics were described by Fuller (1989) as “a live microbial feed supplement which beneficially affects the host animal by improving its intestinal balance.” While prebiotics and probiotics can be used symbiotically, probiotics have moved to the forefront of development for their potential as an alternative to antibiotic growth promoters. Probiotics are also being studied for their potential to reduce food borne pathogens (Reid and Friendship, 2002).

Most probiotics work on the principle of competitive exclusion. A mixture of bacteria can be found in the gut of a healthy animal. If given orally early in life, a mixture of defined beneficial bacteria can be established in the gut (Sun et al., 2005). This beneficial population will prevent the colonization of pathogenic bacteria in the gut. By out competing the pathogenic bacteria for nutrients and binding sites, these beneficial bacteria can exclude the growth of pathogenic or unfavorable bacteria in the gut (Sun et al., 2005). Probiotic or direct-fed microbial culture preparations are most commonly composed of *Lactobacillus*, some *Streptococcus*, *Bifidobacterium*, *Bacillus*, *Enterococcus*, and *Saccharomyces* (Patterson and Burkholder, 2003). Direct-fed microbials are said to work by maintaining the “normal” microflora of the gut, but their mode of action is unclear (Jin et al., 2000). There are said to be four major mechanisms for competitive exclusion in the gut including competition for receptive binding sites, production and secretion of compounds toxic to other microbes, competition for nutrients, as well as generally making the gut environment inhospitable to other microbes

(Rolfe, 1991). These products must have high adhesion ability to epithelial cells of the crop and the intestines (Reid and Friendship, 2002). Edens, et al. (1997) noted that the colonization of lactic acid producing bacteria in the gut of chickens and turkeys has been shown to have beneficial effects particularly related to the production of bacteriocins by these bacteria. For probiotics containing live cultures to be effective, they must also be able to withstand bile salts and the low pH in portions of the gastro-intestinal tract (Reid and Friendship, 2002). In general, the organisms must be able to survive the journey from ingestion through the gastro-intestinal tract to the intestine in order to have an effect (Jin et al., 1998). Probiotics can be given shortly after hatch, and continuous feeding is necessary in order for establishment of a beneficial bacterial population to be successful (Reid and Friendship, 2002).

Results of feeding probiotic cultures are often inconclusive and inconsistent which makes marketing probiotic products difficult (Jin et al., 1998). Some variations can be attributed to the differences in bacterial species used in the specific cultures tested in different research studies or the methods used in preparing the cultures tested (Jin et al., 1998). Several reports show that feeding a probiotic can significantly improve body weight (Jiraphocakul et al., 1990; England et al., 1996; Jin et al., 1998; Jin et al., 2000; Zulkifli et al., 2000; Fritts et al., 2000). However, Owings (1992) found no effect of feeding probiotics on body weight, but this study did report an improvement in feed conversion with the addition of probiotics to the diet even beyond the improvements noted as a result of the antibiotic treatment in this study. Other studies confirm the findings of Owings (1992) and concur that feeding a dietary probiotic can result in improved feed conversion (Jiraphocakul et al., 1990; Jin et al., 1998; Zulkifli et al., 2000;

Fritts et al., 2000). Cavazzoni et al. (1998) noted decreased mortality of birds fed a dietary probiotic. It should be noted that no study reported any advantage of probiotic over an antibiotic growth promoter, simply that the probiotic could produce comparable results to the antibiotic. In addition, a number of studies reported that there was no added benefit to feeding probiotics past a certain level (Jin et al., 1998; Owings, 1992). Fritts et al. (2000) reports that feeding a dietary probiotic can result in reduced coliform and Salmonella counts from the gut of birds fed probiotic cultures. In this study, feeding a probiotic resulted in significant reduction in carcass bacterial contamination (Fritts et al., 2000). Jin et al. (1998) did not report any differences in coliform colonization between any treatment groups in their study.

It is believed that subtherapeutic levels of antibiotics in the feed can counteract some of the negative effects of stress, but there is little evidence to support this notion (Zulkifli et al., 2000). There is evidence that probiotics not only promote growth and stimulate the immune system, but Zulkifli et al. (2000) suggests that probiotics may have their greatest effects under stress-conditions. In their study, Zulkifli et al. (2000) noted that birds on probiotic did have greater body weights during times of heat stress over the both control birds and birds fed antibiotic. It was concluded that these birds gained more under heat stress conditions because they also had increased feed consumption (Zulkifli et al., 2000). Therefore, the birds consumed more probiotic whereas the antibiotic treated birds ate less, giving them less potential for effect.

There has also been work done dealing with a possible interrelationship or synergism between antibiotics and probiotics. Francis et al. (1978) found that probiotics and antibiotics, when fed in combination, did not work synergistically. Birds fed a diet of both antibiotics and probiotics had lower body weights than birds fed either probiotics or antibiotics alone (Francis et al., 1978). Feed efficiency and body weights were significantly improved in birds fed probiotics or antibiotics, but not both (Francis et al., 1978). Francis et al. (1978) concluded that when fed in combination, the antibiotic may inhibit the live organisms of the probiotic. Jiraphocakul et al. (1990) also showed no added benefit to feeding a combination of probiotics and antibiotics, but noted the benefits of both probiotics and antibiotics when fed individually. With increasing public demand for drug-free, natural production, there is a need for further research into any potentially viable alternative to antibiotic growth promoters.

Conclusion

Currently, there is great debate about the implications of using antibiotic growth promoters in animal production. Consumers may have a preference for animals that have been treated with natural products instead of antibiotics and other chemical enhancers (Reid and Friendship, 2002). Because enteric disease causes losses in productivity, increased mortality, in addition to increasing the risk of contamination of food for human consumption (Patterson and Burkholder, 2003), there is a need to find viable alternatives to antibiotics. In addition, nipple drinkers are being examined in the turkey industry to improve the growing environment reducing the need for such growth promoters.

Nipple drinkers have been used in the broiler industry for over a decade because while they generally deliver slightly lower body weights, the benefits of their use seem to supersede this loss in body weight. Nipple drinkers deliver fresh, less contaminated drinking water as well as reduce water spillage. This creates better growing conditions because the reduction in spillage causes drier litter which will intuitively reduce the pathogen load of that litter. Overall, nipple drinkers have been found to yield a bird that is overall healthier than birds on open-watering systems.

Recently, the poultry industry has taken a proactive look at alternatives to antibiotic growth promoters. Everything from the diet, dietary enzymes, antibiotics, normal microflora of the gut, pathogenic gut bacteria, probiotics, and prebiotics can affect the gastro-intestinal tract, its development, and its activity and function (Solis de los Santos et al., 2005). Probiotics and prebiotics have emerged as the most probable alternatives to antibiotics. Probiotics are used to selectively enrich the gut with beneficial bacteria based on the principle of competitive exclusion. Once established, these beneficial bacteria can improve feed efficiency by increasing nutrient absorption and significantly improve body weight in most cases to the same degree as antibiotic growth promoters. Feeding probiotics has also been found to help alleviate some of the effects of stress, and some believe that these mixtures have their greatest effect during times of stress.

References

Aarestrup, F. M., 1995. Occurrence of glycopeptide resistance among *Enterococcus faecium* isolates from conventional and ecological poultry farms. Mcrob. Drug Resist. 1: 255-257.

Aarestrup, F. M., 2003. Effects of termination of AGP use on antimicrobial resistance in food animals. Pages 6-11 in Working papers for the WHO international review panels evaluation. Document WHO/CDS/CPE/ZFK/2003.1a. World Health Organization, Geneva, Switzerland.

Alpharma, 2004. the ultimate lesson we may learn from Denmark. Pages 1-4 For the Record: Straight talk about antibiotics use in food-animal production. http://www.alphama.com/ahd/For_The_Record/html. Accessed March 2006.

Andrews, L. D. and G. C. Harris, 1975. Broiler Performance and Type of Watering Equipment. Poultry Sci. (Abst.) 54: 1727.

Beker, A. and R. G. Teeter, 1994. Drinking Water Temperature and Potassium Chloride Supplementation Effects on Broiler Body Temperature and Performance during Heat Stress. J. Appl. Poultry Res. 3: 87-92.

Berghman, L. R., D. Abi-Ghanem, S. D. Waghela, and S. C. Ricke, 2005. Antibodies: An Alternative for Antibiotics? Poultry Sci. 84: 660-666.

Branton, S. L., J. D. Simmons, B. D. Lott, and D. M. Miles, 2001. Chick Mortality Associated with Elevated Water Lines and Consumption of Wet Litter. J. Appl. Poult. Res. 10: 427-430.

Brown, T. M., M. M. Beck, D. D. Schulte, D. D. Jones, J. H. Douglas, and S. E. Scheideler, 1995. Nipple Waterers for Chick Batteries: Design, Efficiency, and cost Analysis. Poultry Sci. 74: 457-462.

Bywater, R. J., 2005. Identification and Surveillance of Antimicrobial Resistance Dissemination in Animal Production. Poultry Sci. 84: 644-648.

Carlson, S. A., T. S. Frana, and R. W. Griffith, 2001. Antibiotic resistance in *Salmonella enterica* serovar Typhimurium exposed to microncin-producing *Escherchia coli*. Appl. Environ. Microbiol. 67: 3763-3766.

Carpenter, G. H., R. A. Peterson, and W. T. Jones, 1990. Effects of the Presence or Absence of Satellite Chick-Waterers in Conjunction with Nipple-Drinkers on the Mortality and Productive Performance of Broiler Chicks from Young and Old Dams. Poultry Sci. 69: 45-47.

Carpenter, G.H., R.A. Peterson, W.T. Jones, K.R. Daly, and W.A. Harris, 1992. Effects of Two Nipple drinker Types with Different Flow Rates on the Productive Performance of Broiler Chickens During Summerlike Growing Conditions. Poultry Sci. 71: 1450-1456.

Carter, T .A., 1991. Drinking Water Quality for Poultry Production. Pages: 46-52. From: The Proceedings of 1991 Poultry Supervisors Short Course. Poultry Supervisors Short Course, Raleigh**,** NC.

Cavazzoni, V., A. Adami, and C. Castrovilli, 1998. Performance of broiler chickens supplemented with *Bacillus coagulans* as probiotic. British Poultry Science. 39: 526-529.

Cervantes, H., 2004. Why responsible antibiotic use enhances animal and human health. Pages 201-210 in Proceedings of the 2004 Midwest Poultry Federation Convention, St. Paul, MN.

Cleveland, J., T. J. Montville, I. F. Nes, M. L. Chikindas, 2001. Bacteriocins: Safe, natural antimicroials for food preservation. Int. J. Food Microbiol. 71: 1-20.

Counotte, Guillaume, 2000. Understanding the Quality of Drinking Water. World Poultry. 16(5): 34-40.

Dibner, J. J. and J. D. Richards, 2005. Antibiotic Growth Promoters in Agriculture: History and Mode of Action. Poultry Sci. 84: 634-643.

Dodgen, W. H. and G. C. Harris, Jr., 1971. Effect of Number of Birds per Nipple Waterer on Broiler Performance. Poultry Sci. (Abst) 50: 1571.

Donkoh, A., 1989. Ambient temperature: a factor affecting performance and physiological response of broiler chickens. Int. J. Biometerorol. 33:259-265.

Donoghue, D. J., 2003. Antibiotic Residues inPoultry Tissues and Eggs: Human Health Concerns? Poultry Sci. 82: 618-621.

Edens, F. W., C. R. Parkhurst, I. A. Casas, and W. J. Dobrogosz, 1997. Principles of *Ex Ovo* Competative Exclusion and *In Ovo* Administration of *Lactobacillus reuteri*. Poultry Sci. 76: 179-196.

England, J. A., S. E. Watkins, Emad Saleh, and P. W. Waldroup, 1996. Effects of *Lactobacillus reuteri* on Live Performance and Intestinal Development of Male Turkeys. J. Appl. Poultry res. 5: 311-324.

Fairchild, A. S., J. L. Grimes, F. T. Jones, M. J. Wineland, F. W. Edens, and A. E. Sefton, 2001. Effects of Hen Age, Bio-MOS®, and Flavomycin® on Poult Susceptibility to Oral *Escherichia coli* Challenge. Poultry Sci. 80: 562-571.

Feighner, S. D. and M. P. Dashkevicz, 1987. Subtherapeutic levels of antibiotics in pouiltry feeds and their effects on weight gain, feed efficiency, and bacterial cholytaurine hydrolase activity. Appl Environ. Microbiol. 52: 331-336.

Feighner, s. D. and M. P. Dshkevicz, 1988. Effect of dietary carbohydrates on bacterial cholytaurine hydrolase in poultry intestinal homogenates. Appl. Environ. Microbiol. 54: 337-342.

Francis, C., D. M. Janky, A. S. Arafa, and R. H. Harms, 1978. Interrelationship of *Lactobacillus* and Zinc Bacitracin in the Diets of Turkey Poults. Poultry Sci. 57: 1687-1689.

Fritts, C. A., J. H. Dersey, M. A. Motl, E. C. Kroger, F. Yan, J. Si, Q. Jiang, M. M. Campos, A. L. Waldroup, and P. W. Waldroup, 2000. *Bacillus Subtilis* C-3102 (Calsporin) Improves Live Performance and Mcirobiological Status of Broiler Chickens. J. Appl. Poultry Res. 9: 149-155.

Fuller, R., 1989. Probiotics in man and animals. J. Appl. Bacteriol. 66: 365-378.

Gibson, G. R., and M. B. Roberfroid, 1995. Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. J. Nutr. 125: 1401-1412.

Giesen, Andrew, 2005. the value of organic acids in drinking water. World Poultry. 21(12): 15-17.

Harris, G. C., G. S. Nelson, R. L. Seay, and W. H. Dodgen, 1975. Effects of Drinking Water Temperature on Broiler Performance. Poultry Sci. 54: 775-779.

Huff, W. E., G. R. Huff, N. C. Rath, J. M. Balog, and A. M. Donoghue, 2005. Alternatives to Antibiotics: Utilization of Bacteriophage to Treat Colibacillosis and Prevent Foodborne Pathogens. Poultry Sci. 84: 655-659.

Hulet, M. R., 1999. Use of Nipple Drinkers for Turkey Production. Pgs: 50-58. From: The Proceedings of The Twenty-Third Annual North Carolina Turkey Industry Days Conference. Turkey Industry Days, Raleigh, NC.

Jiraphocakul, Saartchit, T.W. Sullivan, and K. M. Shahani, 1990. Influence of a Dried *Bacillus subtilis* culture and Antibiotics on Performance and Intestinal Microflora in Turkeys. Poultry Sci. 69: 1966-1973.

Jin, L. Z., Y. W. Ho, N. Abdullah, and S. Jalaludin, 1998. Growth Performance, Intestinal Microbial Populations, and Serum Cholesterol of Broilers Fed Diets Containing *Lactobacillus* Cultures. Poultry Sci. 77: 1259-1265.

Jin, L. Z., Y. W. Ho, N. Abdullah, and S. Jalaludin, 2000. Digestive and Bacteria Enzyme Activities in Broilers Feed Diets Supplemented with *Lactobacillus* Cultures. Poultry Sci. 79: 886-891.

Joerger, R. D., 2003. Alternatives to Antibiotics: Bacteriocins, Antimicrobial Peptides and Bacteriophages. Poultry Sci. 82: 640-647.

Jones, F. T. and S. C. Ricke, 2003. Observations on the History of the Development of Antimicrobials and Their Use in Poultry Feeds. Poultry Sci. 82: 613-617.

Kudva, I. T., S. Jelacic, P. I. Tarr, P. Youderian, and C. J. Hoyle, 1999. Baiocontrol of *Escherichia coli* with O157-specific bacteriophages. Appl. Environ. Microbiol. 65: 3767-3773.

Lee, S. R. and N. G. Zimmerman, 1987. Effects of Enclosed Nipple Drinkers vs Dome Waterers on Broiler Performance. Poultry Sci. (Suppl.) 66: 132.

Lott, B. D., 1991. The Effect of Feed Intake on Body Temperature and Water Consumption of Male Broilers During Heat Exposure. Poultry Science. 70: 756-759.

Lott, B. D., J.D. May, J. D. Simmons, and S. L. Branton, 2001. The Effect of Nipple Height on Broiler Performance. Poultry Sci. 80: 408-410.

May, J. D. and B. D. Lott, 1992. Feed and Water Consumption Patterns of Broilers at High Environmental Temperatures. Poultry Science. 71: 331-336.

May, J. D., B. D. Lott, and J. D. Simmons, 1997. Water Consumption by Broilers in High Cyclic Temperatures: Bell Versus Nipple Waterers. Poultry Sci. 76: 944-947.

McCracken, V. J. and H. R. Gaskins, 1999. Probiotics and the immune system. Pages 85-111 in Probiotics: A critical review. G. W. Tannock, ed. Horizon Scientific Press, Norfolk, UK.

McMasters, J. D., G. C. Harris, Jr., and T. L. Goodwin, 1971. Effects of Nipple and Trough Watering Systems on Broiler Performance. Poultry Sci. 50: 432-435.

Michel, K., C. Gempesaw, J. Pesek, J. Bacon, and H. Tilmon, 1998. Drinker Technology as an Example of Improving Production Efficiency. J. Appl. Poultry Res. 7: 144-151.

Moore, P. R., A. Evension, T. D. Luckey, E. McCoy, C. A. Elvehjam, and E. B. Hart, 1946. Use of sufasuxidine, streptothricin and streptomycin in nutritional studies with the chick. J. Biol. Chem. 165: 437-441.

Na-Lampang, P. and J. V. Craig, 1990. Research Note: Effects of the Number of Nipple-Waterers on the Waterer Usage and Body Weight of White Leghorn Pullets. Poultry Sci. 69: 1020-1022.

Owings, W. J., 1992. Research Note: Nutritive Effects of a Direct-Fed Microbial Preparation on Growing Turkey Toms. Poultry Sci. 71: 932-935.

Parks, C. W., J. L. Grimes, P. R. Ferket, and A. S. Fairchild, 2001. The Effect of Mannanoligosaccharides, Bambermycins, and Virginiamycin on Performance of Large White Male Market Turkeys. Poultry Sci. 80: 718-723.

Parks, C. W., J. L. Grimes, and P. R. Ferket, 2005. Effects of Virginiamycin and a Mannanoligosaccharide-Virginiamycin Shuttle Program on the Growth and Performance of Large White Female Turkeys. Poultry Sci. 84: 1967-1973.

Patterson, J. A. and K. M. Burkholder, 2003. Application of Prebiotics and Probiotics in Poultry Production. Poultry Sci. 82:627-631.

Pesti, G. M., S. V. Amato, and L. R. Minear, 1985. Water Consumption of Broiler Chickens Under Commercial Conditions. Poultry Science. 64: 803-808.

Reid, G. and R. Friendship, 2002. Alternatives to Antibiotic Use: Probiotics for the Gut. Animal Biotechnology. 13(1): 97-112.

Ricke, S. C., 2003. Perspectives on the Use of Organic Acids and Short Chain Fatty Acids as Antimicrobials. Poultry Sci. 82: 632-639.

Rives, David, 2001. Personal communication regarding a field trial. Prestage Farms, Inc., Clinton, NC.

Rolfe, R. D., 1991. Population dynamics of the intestinal tract. Pages 59-75 in: Colonization Control of Human Bacterial Enteropathogens in Poultry. L.C. Blankenship, ed. Academic Press, Inc., San Diego, CA.

Ross, P. A. and J. F. Hurnik, 1983. Drinking Behavior of Broiler Chicks. *Applied Animal Ethology*. 11: 25-31.

Solis de los Santos, F., M. B. Farnell, G. Téllez, J. M. Balog, N. B. Anthony, A. Torres-Rodreguez, S. Higgins, B. M. Hargis, and A. M. Donoghue, 2005. Effect of Prebiotic on Gut Development and Ascites Incidence of Broilers Reared in a Hypoxic Environment. Poultry Sci. 84: 1092-1100.

Spring, P., C. Wenk, K. A. Dawson, and K. E. Newman, 2000. The Effects of Dietary Mannanoligosaccharides on Cecal Parameters and the Concentrations of Enteric Bacteria in the Ceca of Salmonella-Challenged Broiler Chicks. Poultry Sci. 79: 205-211.

Sun, X., A. McElroy, K. E. Webb, Jr., A. E. Sefton, and C. Novak, 2005. Broiler Performance and Intertinal Alterations when Fed Drug-Free Diets. Poultry Sci. 84: 1294-1302.

Swann, M. M., 1969. Report of Joint Committee on the use of antibiotics in animal husbandry and veterinary medicine. HMSO, London.

Tabler, Tom G., 2003. Nipple Drinker Management Critical to Broiler Performance. AVAIN Advice. 5(1): 9-12.

Van Kampen, M., 1988. Effects of Drinking Water Temperature and Leg Cooling on Heat Stress of Laying Hens (*Gallus domesticus)*. J. therm. Biol. 13(1): 43-47.

Vest, Larry R., 1986. Management of Closed Water Systems for Poultry. Poultry Sci. (Suppl) 65: 139.

Wabeck, Charles J., Lewis E. Carr, and Veronica Byrd, 1994. Broiler Drinker Systems and Seasonal Effects on Eviscerated Carcass and Leaf Fat Weights. J. Appl. Poultry Res. 3: 274-278.

Watkins, Susan, 2000. Water Quality can Influence Poultry Performance. AVIAN Advice. 2(2): 11-12.

Watkins, Susan, 2002. The Campaign for Quality Drinking Water Continues. AVIAN Advice. 4(3): 7-9.

Zulkifli, I., N. Abdullah, N. Mohd. Azrin, and Y. W. Ho, 2000. Growth performance and immune response of two commercial broiler strains fed diets containing *Lactobacillus* cultures and oxytetracycline under heat stress conditions. British Poultry Science. 41: 593-597.

Manusricpt I: The Efficacy of Nipple Drinkers and a Direct-Fed Microbial on the Performance of Large White Commercial Turkey Males.

ABSTRACT

The success of nipple drinkers in the broiler industry has created an interest in using nipple drinkers for turkey production. Public concern about the use of antibiotics as growth promoters in animal production has created the need for alternatives such as probiotics. PrimaLac® (Star Labs, Clarksdale, MO) is a direct-fed microbial that contains viable *Lactobacillus/Streptococcus* species of bacteria. The objective of this study was to test the efficacy of nipple drinkers and the direct-fed microbial, PrimaLac® on turkey performance.

A 2 by 6 factorial design was used (6 drinker types & 2 feed treatments): 1) control Plasson Minibell, 2) Plasson Easy Start, 3) Lubing Traditional (FeatherSoft® high flow nipple with Littergard®), 4) Lubing EasyLine™, 5) ValCo Turkey Drinker, and 6) Ziggity, BigZ Activator. Plasson Mini Bell and Lubing Traditional drinkers were changed to the Plasson Turkey Drinker at 6 weeks of age, Ziggity, BigZ Activator drinkers were changed at 7 weeks of age, and Plasson Easy Start drinkers at 8 weeks of age. ValCo Turkey Drinker and Lubing EasyLine™ drinkers remained in use until market age. Typical turkey diets were formulated with and without PrimaLac®.

BUTA (Lewisburg, WV) Large White male poults (18/pen) were placed in 48 pens (8 pens/treatment) on day of hatch and were reared to 20 weeks of age. Feed consumption (by pen) and body weight were determined at 3, 5-8, 10, 12, 15, and 20 weeks of age. Feed conversion was calculated for each weigh date. Data were analyzed using the General Linear Model procedure of SAS, Inc. The LS Means procedure was

used to separate treatment means ($P \leq 0.05$). There were no feed by drinker type interactions in these two trials.

At 6 weeks of age, body weight of the birds on the Plasson Easy Start and Ziggity, BigZ Activator were less than those on the Plasson Mini Bell. Differences in body weight due to drinker type remained through 10 weeks of age. At 12 weeks of age, body weight of Plasson Easy Start, Lubing EasyLine™, and Ziggity, BigZ Activator birds were no longer different from those reared on Plasson Turkey Bell. Fifteen weeks of age, body weight of birds reared on Lubing Traditional remained less than the birds reared on Plasson Turkey Bell with body weight for ValCo Turkey Drinker intermediate. There were no differences in feed conversion among drinker treatments beyond 15 weeks. Feed conversion was improved for birds fed the direct-fed microbial compared to birds fed the control diet from 3 to 20 weeks of age. Body weight was significantly greater for birds fed the direct-fed microbial through 12 weeks of age. The results of this study show that some nipple drinker systems are effective at least through the brooding period for turkeys with some systems being capable of carrying birds through to market. The direct-fed microbial used herein is a viable alternative candidate to dietary antibiotics for rearing turkeys. Further research, comparing a direct-fed microbial to an antibiotic growth promoter, is needed to ascertain the true viability of direct-fed microbial products.

INTRODUCTION

Recent public controversy over the use of antibiotics, and the subsequent desire for the reduction in antibiotic use, has caused the industry to proactively focus on creating the healthiest production environment possible (Watkins, 2002). Technology can have a positive effect on poultry production. Taking advantage of all possible areas that can be enhanced can lead to more efficient production of poultry (Michel et al., 1998).

The turkey industry is currently interested in the use of nipple drinkers as a replacement for the conventional Bell drinker (Wabeck et al., 1994). The use of nipple waterers improves overall flock health by delivering fresh, uncontaminated drinking water and reducing water spillage, resulting in drier litter which carries a decreased pathogen load (Wabeck et al., 1994). The use of nipple drinkers have shown consistently lower body weights in studies, but field evidence suggests that broilers raised on nipple drinkers had similar body weights to those raised on conventional drinkers (Brown et al., 1995). Most studies agree that birds raised on nipple drinkers have improved feed conversion as compared to birds reared on conventional drinkers.

Antibiotics have been used as growth promoters for over 50 years in the United States and elsewhere (Dibner and Richards, 2005). The benefits of these growth promoters were noted as early as 1946 by Moore et al. (1946). In recent years, the use of the dietary growth promoters has come under increasing scrutiny leading to the ban of their use in the European Union and other countries. Regulations and bans on specific antibiotics are being considered in the Unites States and a total ban seems imminent because of increasing public pressure and consumer preference for a product that has not been treated with antibiotics. Antibiotic resistance, per se, is not very controversial; however, the subsequent impact of this resistance is of great debate (Bywater, 2005). There is relatively little evidence that antibiotic use as growth promoters for animal production is a threat to human health (Bywater, 2005).

Currently, the poultry industry is taking a proactive look at alternatives to antibiotic growth promoters. There are several alternatives currently being experimentally investigated including bacteriophages, bacteriocins, serum therapy, and antimicrobial peptides (Joerger, 2003). Other alternatives like enzymes, organic acids, and mannanoligosaccharide products are currently being used in the field with some success. Two areas of research that seem to show the most promise are prebiotics and probiotics or direct-fed microbials. The purpose of these studies was to examine the effectiveness of nipples drinkers and the direct-fed microbial PrimaLac® in production, evaluate their affect on the performance of commercial turkey males, and evaluate the effect of the direct-fed microbial on birds that may experience water restriction.

MATERIALS AND METHODS

Eight hundred and sixty-four commercial Large White B.U.T.A. (Lewisburg, WV) tom turkeys were reared to 20 weeks of age. There were 18 day-old poults placed in each of 48 pens. A 2 x 6 factorial randomized block design was used with 2 feed treatments and 6 drinker types. The treatments were randomly assigned to 4 halls of 12 pens each. The halls served as experimental blocks to account for any effect of pen location within the house. Each treatment had 4 replications, each of the drinker types is replicated 8 times, while the feed treatments were replicated 24 times.

The feed for this trial was commercially manufactured and the diets were typical of those commonly used in turkey production and were formulated with and without the direct fed microbial PrimaLac®. Samples of all feed batches were analyzed by an independent lab (Star Labs/Forage Research, Inc., Clearwater, FL) to ensure the presence of PrimaLac® in treated feeds and the absence of PrimaLac® in control feeds. PrimaLac®

is a direct-fed microbial cocktail that contains *Lactobacillus acidophilus, Lactobacillus casei, Bifidobacterium bifdium,* and *Enterococcus faecium*. This product and its culture remain viable through the pelleting process. PrimaLac® contains a minimum of 1.0 x 10^8 CFU of *Lactobacillus* organisms per gram.

The control drinker was the conventional bell drinker – the Plasson Mini-Bell (Diversified Imports, Maagan Micheal DN Mensashe, Israel) during brooding and the Plasson Turkey Bell (Diversified Imports, Maagan Micheal DN Mensashe, Israel) during the grow-out period. There were five nipple drinker systems tested and compared to the control: Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel), ValCo Turkey Drinker (Val-Co, Lancaster, PA), Lubing Traditional (FeatherSoft® high flow nipple with Littergard®)(Lubing, Cleveland, TN), Lubing EasyLine™(Lubing, Cleveland, TN), and Ziggity Big-Z Activator (Ziggity Systems, Inc., Middlebury, IN). All nipples were on six-foot sections in each individual pen. The Plasson Easy Start had four cups per six-foot line. The ValCo Turkey Drinker and the Lubing EasyLine™ had two cups per six foot line. The Lubing Traditional (FeatherSoft® high flow nipple with Littergard®) had four nipples per six-foot line. The Ziggity Big-Z Activatior had five nipples per line. All nipple drinkers were managed and operated according to each manufacturer's specifications. Supplemental jug drinkers were used in half the pens, randomized evenly over all treatments, until 3 days of age.

All of the nipple drinkers remained in place at least 6 weeks to simulate commercial brooding duration. At that time, the nipples were changed to the Plasson Turkey Bell as the turkey's mean body weights became significantly lower than the control. The ValCo and Lubing EasyLine™ remained for the entire duration of the trial at the request of the manufacturers. The Lubing Traditional was changed to the Plasson Turkey Bell at 6 weeks. The Ziggity Big-Z Activator was changed to the Plasson Turkey Bell at 7 weeks with the Plasson Easy Start being changed at 8 weeks.

The facility used for this experiment was a curtain-sided house that contained 48 pens that were 2.44m by 2.44m ($5.95m^2$). Concrete floors were covered with clean pine-shavings. Caked litter was removed as necessary and weighed and clean shavings added as needed. Four mixing fans placed throughout each of the two hallways served to mix natural air that was regulated by carefully adjusted side curtains. During brooding, supplemental gas-heaters in each hallway and heat lamps in each pen were used to heat the house and pens. Feed and water were provided *ad libitum* throughout the entire trial. Lighting was continuous for the first 3 days and by natural daylight thereafter (except what light was provided by the heat lamps). Birds were placed in the early summer and reared through the fall of the year. House temperature was kept between 88°F and 94°F for the first 10 days and was then gradually decreased by 5°F each week to ambient temperature. High and low house temperatures were recorded twice daily in four locations throughout the house for the entire length of the trial.

Special precautions were taken in order to ensure that feed treatments remained separated and control pens remained uncontaminated. Feed was delivered to the same bulk bins each time and separate augers were used for each bin. The feed was stored in 1000 lb feed carts for hand feeding with lids on the boxes to prevent dust contamination. Each feed treatment had designated buckets used for feeding. Twenty-four inch wooden partitions were placed around the perimeter of each pen as a physical barrier to contamination. All work, including feed weighing, and maintenance, was done in control pens first. Tools, such as shovels and pitch-forks, were also special to feed treatment. When working in treated pens, boots were worn and removed upon exiting the pen. Farm staff washed and sanitized their hands after working in treated pens. The concrete hallways were washed after work was complete in treated pens and again before work began in control pens.

Body weight and feed consumption were measured at weeks 3, 5, 6, 7, 8, 10, 12, 15, and 20. Body weights were measured by pen at 3 and 5 weeks and individually at all subsequent measurement dates. Feed consumption was determined by pen at each weigh day. Period and cumulative feed conversions were calculated using the body weight and feed consumption data and was expressed per bird. Period feed conversion was calculated as a feed:gain ratio for that period. Cumulative feed conversion was calculated using total weight and total feed consumed. Mortality and culled birds were recorded as they occurred, and their weights were used to adjust feed conversion.

Litter moisture was measured beneath the drinker at 6 and 20 weeks. Composite samples were taken beneath the drinkers. A representative sample was taken from the composite, weighed, and dried for no less than 24 hours. A second weight was taken after the drying period. These weights were used to calculate percent moisture based on the following equation:

$$[(\text{Sample Weight 1} - \text{Sample Weight 2})/\text{Sample Weight 1}] \times 100 = \%\ \text{Moisture}$$

Fresh fecal samples were analyzed to count coliform bacteria in each sample using the procedure described in the FDA Bacteriological Analytical Manual. These samples were also checked for the presence of *salmonella* using the procedure outlined in Chapter 4 of the USDA Microbiology Laboratory Guidebook.

Data were analyzed using the GLM Procedure of SAS.V8, Inc. The LS Means procedure was used to separate treatment means ($p \leq 0.05$). The pen served as the experimental unit for all performance data.

RESULTS

No effect of supplemental drinkers was seen at 3 weeks of age (BW with supplemental drinkers 693g±1g and without supplemental drinkers 695±1g). Mortality was not significant at any point due to treatment (data not shown). Mortality during the brooding period was 2% with 95% livability for the entire trial excluding 3% culls. There were no body weight differences due to treatment at placement (59±1g) (Table 1). At three weeks of age, the body weights of the poults began to differ by drinker type. The Plasson Bell yielded the heaviest bird at 716g with the birds reared on the Ziggity, Big-Z Activator being different from the Bell treatment with birds weighing 690g with the Plasson Easy Start, Lubing EasyLine™, and ValCo Turkey Drinker being intermediate at 3 weeks of age. At 3 weeks of age, the Lubing Traditional Nipple birds had lower body weight (647±7g) than all other drinker types. The pattern observed at 3 weeks of age, continued at 5 weeks of age. Birds reared on the Plasson Easy Start, weighed 2.37kg, became different from the Plasson Bell (2.50±0.04kg) at 6 weeks with all others intermediate. At 6 weeks, the birds raised on the Lubing Traditional Nipple continued to be lighter than those reared on all other drinkers. Therefore, the Lubing Traditional Nipple was changed to the Plasson Turkey Bell at 6 weeks of age. Body weights of toms by drinker type from 7 to 20 weeks of age are presented in Table 2. By 7 weeks of age, the body weights of the birds on all nipple drinkers were lower than the body weights of those birds on the Plasson Bell (3.45±0.04kg), and this trend continued through 10 weeks of age. By 12 weeks of age, the body weights of those birds that had been on the Ziggity, Big-Z Activator and Plasson Easy Start, which were changed to the Plasson Bell at 7 and 8 weeks of age respectively, were no longer significantly different from the body weights of those birds reared on the control drinker. The body weights of birds reared on the Lubing EasyLine^{TM} (9.48±0.12kg) were also not significantly different from the controls at 12 weeks of age. Differences in body weights at 15 weeks of age were similar to those observed at 12 weeks of age, except the ValCo Turkey Drinker was intermediate. By the end of the grow-out period, there were no significant differences in body weight between drinkers except the ValCo Turkey Drinker and the Lubing Traditional Nipple, which yielded significantly reduced body weights compared to all other drinker types, weighing 20.55 kg and 20.67±0.16kg respectively.

Table 3 contains body weights by feed treatment from placement to six weeks. The body weights of those birds being fed the direct-fed microbial were significantly heavier than the body weights of the control birds from placement to 5 weeks of age. At 5 weeks of age, birds fed the direct-fed microbial weighed 1.72±0.01kg, which was heavier, compared to the body weights of birds on the control diet weighing 1.68±0.01kg. The body weights of toms from 7 weeks of age to 12 weeks of age by feed treatment are shown in Table 4. The birds fed the direct-fed microbial were heavier than the controls from 7 weeks of age to 12 weeks of age. From 15 weeks of age through the end of the trial, there were no significant differences in body weight between the birds being fed the direct-fed microbial and the control birds.

Feed conversion for toms by drinker type from placement to six weeks of age is presented in Table 5 and from 7 to 20 weeks of age is presented in Table 6. There were no significant differences in cumulative feed conversion by drinker type at any other point except at 12 and 20 weeks of age, which coincided with periods of high cyclic temperatures. Cumulative feed conversion was significantly improved for the birds being fed the direct-fed microbial compared to the feed conversion of the control birds for the entire trial (Figure 1).

Cumulative feed consumption per bird ages 7 to 20 weeks of age followed a similar pattern to that seen in body weights through the brooding period (Table 8). By 8 weeks of age, the feed consumption per bird for birds reared on all the nipple drinkers was less than the feed consumption of birds on the Plasson Bell (7.39±0.09kg per bird). Birds raised on the nipple drinkers continued to have a lower feed consumption than the control birds through 12 weeks of age, except the birds reared on the Lubing EasyLine™ (15.86±0.28kg per bird) which were intermediate at 10 and 12 weeks of age. There was no difference in feed consumption by drinker type from 15 to 20 weeks of age. Cumulative feed consumption was only different by feed treatment at 3 weeks of age with birds being fed the direct-fed microbial consuming 1.02±0.01kg per bird and the controls consuming 1.07±0.01kg per bird (Table 9). Cumulative feed consumption by treatment was not significant from 7 to 20 weeks of age (Table 10).

Litter moisture (%) beneath the drinker was lower at 6 weeks of age in all nipple drinker pens, except the ValCo Turkey Drinker (51.13%±3.56%), compared to litter in Plasson Bell pens (49.48%±3.56%) (Table 11). At 20 weeks of age, only those drinkers that remained for the duration of the trial were tested. At this point, litter moisture was not significantly different beneath the Lubing EasyLine™ (53.49%±1.40%) compared to litter moisture beneath the Plasson Bell (56.92%±1.40%). The ValCo Turkey Drinker

(64.34%±1.40%) had significantly higher litter moisture at 20 weeks of age compared to the Plasson Bell.

The coefficient of variation of body weight followed a similar trend for all drinkers throughout the trial. Coefficient of variation of body weights continuously decreased from 6 to 20 weeks of age, with the range from highest coefficient of variation and lowest coefficient of variation staying relatively constant. There were no significantly differences in coefficient of variation by drinker type. This decreasing trend was also seen by feed treatment. There were no differences in coefficient of variation by feed treatment at any age measured, and the margin between the two treatments narrowed as the birds aged.

DISCUSSION

Because of current public debate about the use of dietary subtherapeutic antibiotics as growth promoters, the poultry industry is currently examining ways to enhance the growing environment and reduce the use of antibiotic growth promoters. In the broiler industry, nipple drinkers have been the predominant drinker used for more than a decade. These drinkers have several advantages including improved feed conversion, delivery of clean, less contaminated drinking water, reduced water spillage, and overall drier litter. With this, pathogen load is reduced which not only aids in creating a more sanitary growing environment, but also yields an overall healthier bird (Branton et al., 2001).

There are very little data on the use of nipple drinkers in turkey production, and their use for turkey rearing has shown mixed results. Hulet (1999) found that nipple drinkers were effective in brooding conditions or up to 10 weeks of age. However, the results of this study showed, similar to others, reduced body weights yet comparable or improved feed conversion. In a field trial by Rives (2001), body weights were reduced at 5-6 weeks, but equalized by 10-12 weeks when birds were switched to the Plasson Turkey Bell for the grow-out phase. Both the current study and the Rives (2001) field trial reported that a combination of the two drinker types may be optimal in certain instances. For example, in the current study, birds which were brooded on the Plasson Easy Start and Ziggity, Big-Z Activator and then switched to the Plasson Bell performed as well as the control birds. Conversely, some new systems seem to work well for the entire life of the flock. Birds on the Lubing EasyLine™, which remained throughout this study, exhibited comparable performance to that seen of birds on the conventional Plasson Turkey Bell.

Hulet (1999) noted many advantages of nipple drinkers that can offset the disadvantage of reduced body weight. Lee and Zimmerman (1987), who conducted similar trials with broilers, concluded that the benefits of nipple drinkers are enough to outweigh the decreased body weight by caused by the use of nipple drinkers. It is generally accepted that birds raised on nipple drinkers have improved feed conversion ratios (Wabeck et al., 1994; Carpenter et al., 1990; Brown et al., 1995). On a performance basis, even though body weight is reduced, feed conversion is often greatly improved, and overall bird health is improved due to the access to clean, less contaminated drinking water. Since nipple drinkers are a closed system, they maintain drier litter which also contributes to improving growing conditions. Practically, nipple systems provide growers with a labor saving alternative to traditional open-water systems. Nipple drinkers need less cleaning and maintenance and allow for easier administration and less wasting of vaccinations and medications. These systems do require more intense management than do conventional open-water systems, and producers must be more knowledgeable to manage such systems (Tabler, 2003).

The current study, like the Rives (2001) field trial, showed that birds experienced apparent compensatory growth when put back on the Plasson Turkey Bell. True compensatory growth is not seen in actual growing conditions because if birds were growing at maximum genetic potential, there would not be an opportunity for true compensatory growth to occur. For example, optimum growing conditions yield optimum growth, but this does not necessarily equal 100% of genetic potential. If water consumption drives feed consumption which in turn drives growth rate, then nipple drinkers that limit water consumption would ultimately limit growth. Apparent compensatory growth is observed under the assumption that the control birds were not growing at 100% of genetic potential, which gave the water restricted birds an opportunity to match the body weight of the control birds when given access to adequate amounts of water. When significant differences between drinker types initially disappeared at 12 weeks, it seemed as though this was only a statistical anomaly and not a biological response given the increases noted in SEM. However, by the end of the study, it was apparent that the birds that had been water restricted by the nipple drinkers had recovered body weight when the drinker was changed .

There are many beneficial bacteria that can work to promote growth, but not all of these bacteria thrive under commercial growing conditions. Current direct-fed microbial research focuses on finding beneficial dietary microbes that perform under commercial growing conditions, and promoting the growth of these microbes under these conditions is essential since some bacteria are not naturally occurring in the gut. Beneficial bacteria in the gut are capable of improving feed efficiency by increasing nutrient absorption (Solis de los Santos et al., 2005). There are said to be four major mechanisms for competitive exclusion in the gut including competition for receptive binding sites, production and secretion of compounds toxic to other microbes, competition for nutrients, as well as generally making the gut environment inhospitable to other microbes (Rolfe, 1991). These products must have high adhesion ability to epithelial cells of the crop and the intestines (Reid and Friendship, 2002). Edens, et al. (1997) noted that the colonization of lactic acid producing bacteria in the gut of chickens and turkeys has been shown to have beneficial effects particularly related to the production of bacteriocins by these bacteria.

The effect of feeding direct-fed microbials has been highly variable. Some of this variation could be attributed to differences in bacterial species used in the specific cultures tested or the methods used in preparing the cultures (Jin et al., 1998). Early reports by Carlson et al. (1979) did not show any effect on body weight or feed conversion of feeding direct-fed microbials to tom turkeys fed to 24 weeks of age. Owings (1992) found no effect of feeding probiotics on body weight, but did report an improvement in feed conversion with the addition of probiotics to the diet even beyond the improvements noted as a result of the antibiotic treatment in that study. In the current study, while there was no difference in tom body weight at 20 weeks, feed conversion was statistically improved for birds fed direct-fed microbial through 20 weeks of age. Other studies confirm the findings of Owings (1992) and concur that feeding a dietary probiotic can result in improve feed conversion (Jiraphocakul et al., 1990; Jin et al., 1998;

Zulkifli et al., 2000; Fritts et al., 2000). There are other reports that agree with the findings of the current study. Potter et al. (1979) reported that birds fed *Lactobacillus acidophilus* were heavier than controls at 8, 10, and 12 weeks of age, but found no effect on feed conversion. The current study also noted a difference in body weight with the birds fed the direct-fed microbial being heavier than controls though 12 weeks of age, but not thereafter.

In reviewing reports on direct-fed microbial studies, the possibility of cross-contamination between the direct-fed microbial treatments and control fed birds must be considered. If contamination of control birds occurs, the treatment effect can be lost. England, et al. (1996) noted contamination of control birds from across an isle during a *Bacillus subtilus* feeding study. In later studies, England, et al. (1996) reportedly took extensive measures to prevent contamination of control birds. These measures are supported by observations and efforts made by Tortuero (1973), Watkins and Miller (1983a), Watkins and Miller (1983b), and Fritts, et al. (2000) using chicks in similar studies. In this study, there were also special precautionary measures taken to try to ensure that cross-contamination did not occur. In any study testing the effect of direct-fed microbials, unless the author describes the methods used to prevent cross-contamination, the results must be viewed with caution particularly if no effect was reported.

While any explanation of the mode of action of direct-fed microbials is beyond the scope of this study, McCracken and Gaskins (1999) propose that the bacteria that naturally occur in the gut compete with their host for nutrients, secrete toxic compounds, and can cause on-going inflammatory immune responses in the gut. Direct-fed microbial products adhere to epithelial cells of the crop and intestines (Reid and Friendship, 2002), and enhance the mucosal layer that covers the intestinal surfaces (Fuller, 1989).

Further research is needed to ascertain how nipple drinkers affect the performance of commercial turkeys. Research in rearing commercial turkeys on nipple drinkers is so limited that there is need for further research in this area particularly under field conditions. Additionally, with respect to direct-fed microbials, further research is needed to better understand how direct-fed microbials interact with other feed ingredients and feed additives. Since certain direct-fed microbials have been shown to survive commercial milling processes such as pelleting, additional testing of direct-fed microbials is needed, particularly under field conditions.

CONCLUSIONS

From this study, it can be concluded that some nipple drinkers systems are effective through the brooding period for turkeys and some systems are capable of supporting adequate growth of birds to market age. While nipple drinkers generally cause reduced market body weights, the significant improvement in feed conversion and litter moisture may outweigh the effects of reduced body weights. Litter moisture can be significantly reduced with the use of nipple drinkers if managed properly during rearing. The direct-fed microbial used in this study yielded increased body weights through 12 weeks of age and improved feed conversion throughout the entire length of the trial. However, this effect was seen universally, with no added effect for birds that experienced reduced growth as a result of being reared on nipple drinkers. Therefore, the direct-fed microbial used herein is a viable alternative candidate to dietary antibiotics for rearing turkeys. Further research, comparing a direct-fed microbial to an antibiotic growth promoter, is needed to ascertain the true viability of direct-fed microbial products.

REFERENCES

Anonymous, 1998. Chapter 4: Isolation and Identification of *Salmonella* from Meat, Poultry and Egg Products. Pages 4:1-14 in USDA/FSIS Microbiology Laboratory Guidebook. 3rd ed. Volume 1. US Government Printing Office, Washington, D.C.

Branton, S. L., J. D. Simmons, B. D. Lott, and D. M. Miles, 2001. Chick Mortality Associated with Elevated Water Lines and Consumption of Wet Litter. J. Appl. Poult. Res. 10: 427-430.

Brown, T.M., M.M. Beck, D.D. Schulte, D.D. Jones, J.H. Douglas, and S.E. Scheideler, 1995. Nipple Waterers for Chick Batteries: Design, Efficiency, and cost Analysis. Poultry Sci. 74: 457-462.

Bywater, R. J., 2005. Identification and Surveillance of Antimicrobial Resistance Dissemination in Animal Production. Poultry Sci. 84: 644-648.

Carlson, C. W., R. A. Nelson, and A. B. Kashani, 1979. Effects of probiotics on turkeys and laying hens. Pages 18-20 in: Proceedings of the 11th South Dakota State University Poultry Day, Brookings, SD.

Carpenter, G. H., R. A. Peterson, and W. T. Jones, 1990. Effects of the Presence or Absence of Satellite Chick-Waterers in Conjunction with Nipple-Drinkers on the Mortality and Productive Performance of Broiler Chicks from Young and Old Dams. Poultry Sci. 69: 45-47.

Dibner, J. J. and J. D. Richards, 2005. Antibiotic Growth Promoters in Agriculture: History and Mode of Action. Poultry Sci. 84: 634-643.

Edens, F. W., C. R. Parkhurst, I. A. Casas, and W. J. Dobrogosz, 1997. Principles of *Ex Ovo* Competative Exclusion and *In Ovo* Administration of *Lactobacillus reuteri*. Poultry Sci. 76: 179-196.

England, J. A., S. E. Watkins, Emad Saleh, and P. W. Waldroup, 1996. Effects of *Lactobacillus reuteri* on Live Performance and Intestinal Development of Male Turkeys. J. Appl. Poultry res. 5: 311-324.

Feng, P., S. D. Weagant, and M.A. Grant, 1998. Chapter 4: Enumeration of *Escherichia coli* and the Coliform Bacteria. Pages 4.01-4.29 in the Food and Drug Administration Bacteriological Analytical Manual. 8th ed. Rev.A. AOAC International, Gaithersburg, MD.

Fritts, C. A., J. H. Dersey, M. A. Motl, E. C. Kroger, F. Yan, J. Si, Q. Jiang, M. M. Campos, A. L. Waldroup, and P. W. Waldroup, 2000. *Bacillus Subtilis* C-3102 (Calsporin) Improves Live Performance and Mcirobiological Status of Broiler Chickens. J. Appl. Poultry Res. 9: 149-155.

Fuller, R., 1989. Probiotics in man and animals. J. Appl. Bacteriol. 66: 365-378.

Jin, L. Z., Y. W. Ho, N. Abdullah, and S. Jalaludin, 1998. Growth Performance, Intestinal Microbial Populations, and Serum Cholesterol of Broilers Fed Diets Containing *Lactobacillus* Cultures. Poultry Sci. 77: 1259-1265.

Jiraphocakul, Saartchit, T.W. Sullivan, and K. M. Shahani, 1990. Influence of a Dried *Bacillus subtilis* culture and Antibiotics on Performance and Intestinal Microflora in Turkeys. Poultry Sci. 69: 1966-1973.

Joerger, R. D., 2003. Alternatives to Antibiotics: Bacteriocins, Antimicrobial Peptides and Bacteriophages. Poultry Sci. 82: 640-647.

Lee, S.R. and N.G. Zimmerman, 1987. Effects of Enclosed Nipple Drinkers vs Dome Waterers on Broiler Performance. Poultry Sci. (Suppl.) 66: 132.

McCracken, V. J. and H. R. Gaskins, 1999. Probiotics and the immune system. Pages 85-111 in Probiotics: A critical review. G. W. Tannock, ed. Horizon Scientific Press, Norfolk, UK.

Michel, K., C. Gempesaw, J. Pesek, J. Bacon, and H. Tilmon, 1998. Drinker Technology as an Example of Improving Production Efficiency. J. Appl. Poultry Res. 7: 144-151.

Moore, P. R., A. Evanson, T. D. Luckey, E. McCoy, C. A. Elvehjen, and E. B. Hart, 1946. Use of sulfasuxidine, streptothricin, and streptomycinin nutritional studies with the chick. J. Biol. Chem. 165: 437-441.

Owings, W. J., 1992. Research Note: Nutritive Effects of a Direct-Fed Microbial Preparation on Growing Turkey Toms. Poultry Sci. 71: 932-935.

Potter, L. M., L. A. Nweborn, C. M. Parsons, J. R. Shelton, and J. S. Crawford, 1979. Effects of protein, poultry by-product meal, and dry *Lactobacillus acidophilus* culture additions to diets of growing turkeys. Poultry Sci. 58: 1095 (abstract).

Reid, G. and R. Friendship, 2002. Alternatives to Antibiotic Use: Probiotics for the Gut. Animal Biotechnology. 13(1): 97-112.

Rolfe, R. D., 1991. Population dynamics of the intestinal tract. Pages 59-75 in: Colonization Control of Human Bacterial Enteropathogens in Poultry. L.C. Blankenship, ed. Academic Press, Inc., San Diego, CA.

SAS Institute, 1992. SAS User's Guide. Version 6.08. SAS Institute, Inc., Cary, NC.

Solis de los Santos, F., M. B. Farnell, G. Téllez, J. M. Balog, N. B. Anthony, A. Torres-Rodreguez, S. Higgins, B. M. Hargis, and A. M. Donoghue, 2005. Effect of Prebiotic on Gut Development and Ascites Incidence of Broilers Reared in a Hypoxic Environment. Poultry Sci. 84: 1092-1100.

Tabler, Tom G., 2003. Nipple Drinker Management Critical to Broiler Performance. AVAIN Advice. 5(1): 9-12.

Tortuero, F., 1973. Infulence of the implantation of *Lactobacillus acidophilus* in chicks on the growth, feed utilization, malabsorptin of fats syndrome and intestinal flora. Poultry Sci. 52: 197-203.

Wabeck, Charles J., Lewis E. Carr, and Veronica Byrd, 1994. Broiler Drinker Systems and Seasonal Effects on Eviscerated Carcass and Leaf Fat Weights. J. Appl. Poultry Res. 3: 274-278.

Watkins, Susan, 2002. The Campaign for Quality Drinking Water Continues. AVIAN Advice. 4(3): 7-9.

Watkins, B. A., and B. F. Miller, 1983a. Competitive intestinal exclusion of avian pathogens by *Lactobacillus acidophilus* in gnotobiotic chicks. Poultry Sci. 62: 1772-1779.

Watkins, B. A., and B. F. Miller, 1983b. Colonization of *Lactobacillus acidophilus* in gnotobiotic chicks. Poultry Sci. 62: 2152-2157.

Zulkifli, I., N. Abdullah, N. Mohd. Azrin, and Y. W. Ho, 2000. Growth performance and immune response of two commercial broiler strains fed diets containing *Lactobacillus* cultures and oxytetracycline under heat stress conditions. British Poultry Science. 41: 593-597.

Table 1. Body weight of Large White commercial turkey males from placement to six weeks of age brooded on different drinker types[1].

	Industry Standard	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]								
0[4]		59	59	59	60	59	59	1
3[5]	0.763	0.716[a]	0.703[ab]	0.647[c]	0.709[ab]	0.700[ab]	0.690[b]	0.007
5[5]	1.95	1.77[a]	1.73[ab]	1.49[c]	1.75[ab]	1.74[ab]	1.71[b]	0.02
6[5]	2.80	2.50[a]	2.37[b]	2.04[c]	2.44[ab]	2.42[ab]	2.37[b]	0.04

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[3] Age 0 is day of hatch. Ages 3-6 are in weeks.

[4] Body weight in grams for day of hatch.

[5] Body weight in kg for ages 3-6 weeks.

[a, b, c] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 2. Body weight of Large White commercial turkey males from seven to twenty weeks of age reared on different drinker types[1α].

	Industry Standard	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]								
7	3.75	3.45[a]	3.28[b]	2.94[c]	3.34[b]	3.32[b]	3.28[b]	0.04
8	4.80	4.43[a]	4.24[b]	3.85[c]	4.26[b]	4.24[b]	4.21[b]	0.05
10	7.13	7.09[a]	6.80[b]	6.25[c]	6.87[b]	6.74[b]	6.78[b]	0.07
12	9.63	9.74[a]	9.42[a]	8.95[b]	9.48[a]	8.97[b]	9.45[a]	0.12
15	13.48	13.76[a]	13.64[a]	13.04[b]	13.82[a]	13.33[ab]	13.62[a]	0.18
20	19.67	21.27[a]	21.19[a]	20.67[b]	21.33[a]	20.55[b]	21.21[a]	0.16

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[3] Ages 7- 20 are in weeks and weights are measured in kg.

[a, b, c] Means within a row with different superscripts are significantly different ($p<0.05$).

[α] Nipple drinkers were changed to the Plasson Turkey Bell as the body weights of the birds on those drinkers fell significantly behind the body weights of birds started on the Plasson Turkey Bell. The Lubing Traditional Nipple was changed at 6 weeks, the Ziggity, Big-Z Acitvator at 7 weeks, and the Plasson Easy Start at 8 weeks. The Lubing EasyLine™ and the ValCo Turkey Drinker were left for the duration of the project at the request of those companies.

Table 3. Body weight of Large White commercial turkey males from placement to six weeks of age reared on different feed treatments.

Age[2]	Industry Standard	DFM[1]	Control	SEM
0[3]		59	59	1
3[4]	0.763	0.703[a]	0.686[b]	0.004
5[4]	1.95	1.72[a]	1.68[b]	0.01
6[4]	2.80	2.37	2.35	0.02

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Age 0 is day of hatch. Ages 3-6 are in weeks.
[3] Body weight in grams for day of hatch.
[4] Body weight in kg for ages 3-6 weeks.
[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 4. Body weight of Large White commercial turkey males from seven weeks of age to market reared on different feed treatments.

	Industry Standard	DFM[1]	Control	SEM
Age[2]				
7	3.75	3.34[a]	3.19[b]	0.02
8	4.80	4.34[a]	4.07[b]	0.03
10	7.13	6.87[a]	6.64[b]	0.04
12	9.63	9.47[a]	9.20[b]	0.07
15	13.48	13.55	13.51	0.12
20	19.67	21.08	20.99	0.09

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Ages 7-20 are in weeks and body weights are measured in kg.
[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 5. Cumulative feed conversion of Large White commercial turkey males from placement to six weeks of age brooded on different drinker types[1].

	Industry Standard	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]								
3	1.47	1.50	1.48	1.53	1.51	1.48	1.51	0.02
5	1.62	1.53	1.50	1.54	1.52	1.50	1.52	0.02
6	1.67	1.56	1.55	1.58	1.57	1.56	1.57	0.02

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).
[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.
[3] Ages 3-6 are in weeks.

Table 6. Cumulative feed conversion of Large White commercial turkey males from seven weeks of age to market reared on different drinker types[1α].

	Industry Standard	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]								
7	1.74	1.56	1.59	1.56	1.58	1.57	1.59	0.02
8	1.81	1.67	1.64	1.60	1.66	1.64	1.62	0.02
10	1.95	2.00	2.00	1.97	2.02	1.99	1.98	0.03
12	2.09	2.00^{a}	1.95^{ab}	1.89^{b}	1.99^{a}	2.01^{a}	1.95^{ab}	0.03
15	2.32	2.17	2.11	2.08	2.08	2.11	2.13	0.04
20	2.75	2.62^{a}	2.55^{ab}	2.49^{b}	2.51^{b}	2.54^{ab}	2.63^{a}	0.04

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[3] Ages 7-20 are in weeks.

[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

[α] Nipple drinkers were changed to the Plasson Turkey Bell as the body weights of the birds on those drinkers fell significantly behind the body weights of birds started on the Plasson Turkey Bell. The Lubing Traditional Nipple was changed at 6 weeks, the Ziggity, Big-Z Acitvator at 7 weeks, and the Plasson Easy Start at 8 weeks. The Lubing EasyLine™ and the ValCo Turkey Drinker were left for the duration of the project at the request of those companies.

Table 7. Cumulative feed consumption (kg/bird) of Large White commercial turkey males from placement to six weeks of age brooded on different drinker types[1].

	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]							
3	1.08[a]	1.04[ab]	0.99[b]	1.07[a]	1.04[ab]	1.04[ab]	0.02
5	2.71[a]	2.59[b]	2.29[c]	2.66[ab]	2.62[ab]	2.60[b]	0.04
6	3.90[a]	3.75[ab]	3.24[c]	3.84[ab]	3.77[ab]	3.74[b]	0.06

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).
[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.
[3] Ages 3-6 are in weeks and weights are in kg.

Table 8. Cumulative feed consumption (kg/bird) of Large White commercial turkey males from seven weeks of age to market reared on different drinker types[1α].

Age[3]	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
7	5.34[a]	5.22[a]	4.58[b]	5.27[a]	5.22[a]	5.18[a]	0.07
8	7.39[a]	6.97[b]	6.18[c]	7.06[b]	6.94[b]	6.84[b]	0.09
10	11.24[a]	10.66[b]	9.59[c]	10.89[ab]	10.50[b]	10.46[b]	0.15
12	16.35[a]	15.31[b]	14.24[c]	15.86[ab]	15.22[b]	15.40[b]	0.28
15	26.75	25.65	24.34	25.62	25.57	25.72	0.50
20	51.77	50.77	49.44	50.41	48.93	52.49	0.99

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[3] Ages 7-20 are in weeks and weights are in kg.

[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

[α] Nipple drinkers were changed to the Plasson Turkey Bell as the body weights of the birds on those drinkers fell significantly behind the body weights of birds started on the Plasson Turkey Bell. The Lubing Traditional Nipple was changed at 6 weeks, the Ziggity, Big-Z Acitvator at 7 weeks, and the Plasson Easy Start at 8 weeks. The Lubing EasyLine™ and the ValCo Turkey Drinker were left for the duration of the project at the request of those companies.

Table 9. Cumulative feed consumption (kg/bird) of Large White commercial turkey males from placement to six weeks of age reared on different feed treatments.

	DFM[1]	Control	SEM
Age[2]			
3	1.02[b]	1.07[a]	0.01
5	2.56	2.59	0.02
6	3.69	3.72	0.03

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Ages 3-6 are in weeks and weights are in kg.
[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 10. Cumulative feed consumption (kg/bird) of Large White commercial turkey males from seven weeks of age to market reared on different feed treatments.

Age[2]	DFM[1]	Control	SEM
7	5.14	5.13	0.04
8	6.96	6.83	0.05
10	10.54	10.57	0.08
12	15.44	15.34	0.16
15	25.52	25.69	0.29
20	50.11	51.16	0.57

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Ages 7-20 are in weeks and body weights are measured in kg.

Table 11. Litter moisture[1] (%) beneath the drinker of Large White commercial turkey males from placement to market reared on different drinker types[2α].

	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[3]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[4]							
6[4]	49.48[a]	34.00[b]	28.46[b]	34.06[b]	51.13[a]	28.98[b]	3.56
20[4]	56.92[b]			53.49[b]	64.34[a]		1.40

[1] Litter moisture (%) was taken as a composite sample beneath the drinker.

[2] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[3] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[4] Ages 3-6 are in weeks and values are measured as percent litter moisture.

[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

[α] Nipple drinkers were changed to the Plasson Turkey Bell as the body weights of the birds on those drinkers fell significantly behind the body weights of birds started on the Plasson Turkey Bell. The Lubing Traditional Nipple was changed at 6 weeks, the Ziggity, Big-Z Acitvator at 7 weeks, and the Plasson Easy Start at 8 weeks. The Lubing EasyLine™ and the ValCo Turkey Drinker were left for the duration of the project at the request of those companies.

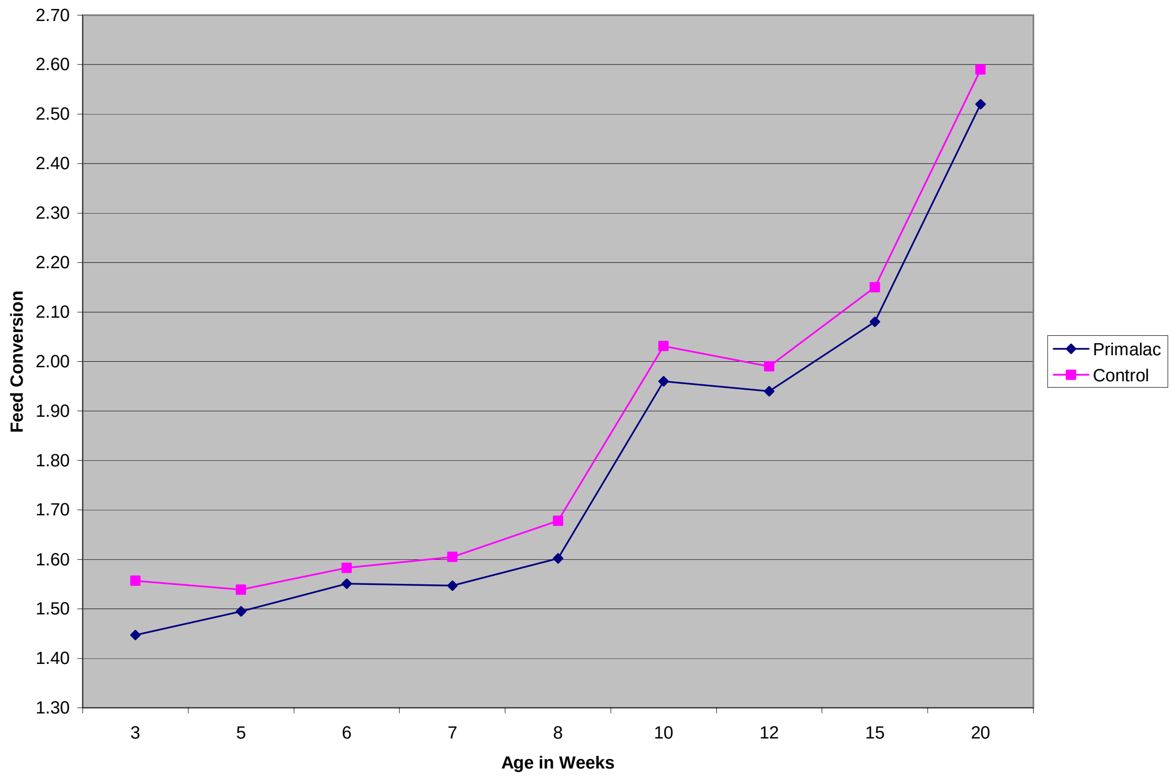

Figure 1. Effect of feed treatment[1] on cumulative feed conversion[2] of Large White commercial turkey males from placement to twenty weeks of age

[1] Birds were fed diets with and without the direct-fed microbial PrimaLac® (Star Labs, Clarksdale, MO).

[2] Cumulative Feed Conversion was significantly different at all ages where measured (SEM=0.028).

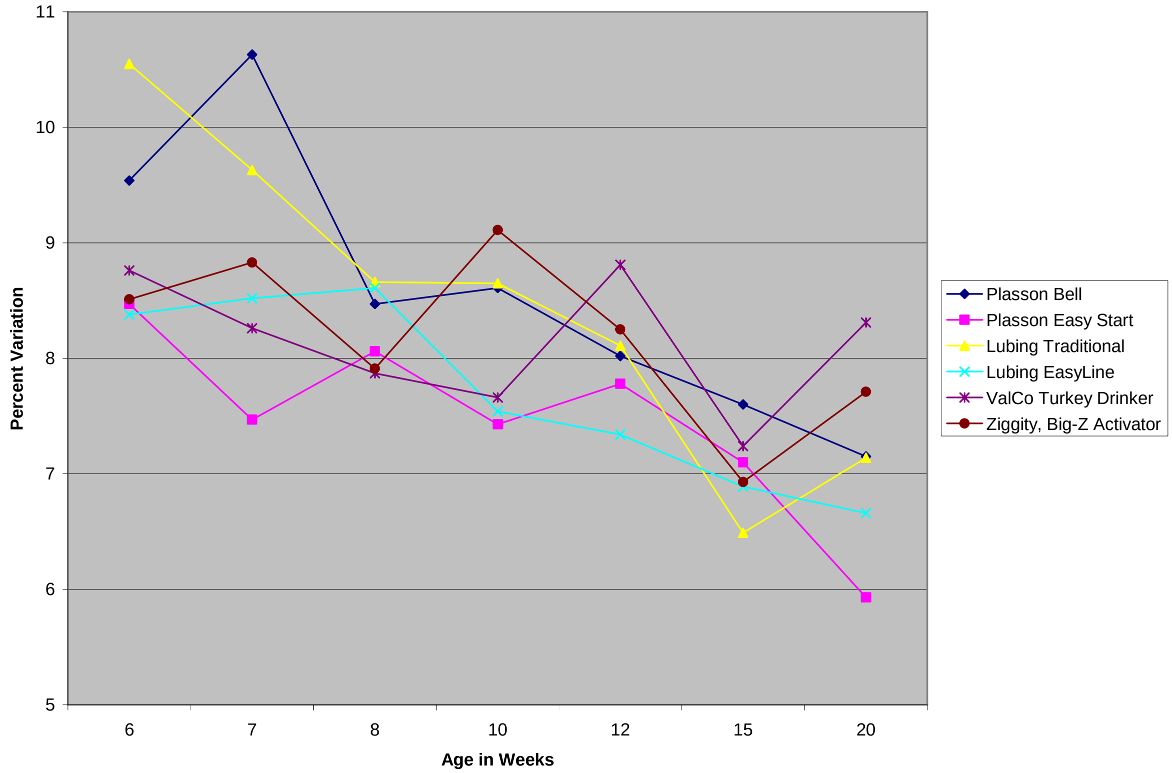

Figure 2. Coefficient of variation[1] of body weight of Large White commercial turkey males reared on different drinker types[2α] from six to twenty weeks.

[1] There are no significant differences at any age (SEM=0.77).

[2] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[α] Nipple drinkers were changed to the Plasson Turkey Bell as the body weights of the birds on those drinkers fell significantly behind the body weights of birds started on the Plasson Turkey Bell. The Lubing Traditional Nipple was changed at 6 weeks, the Ziggity, Big-Z Acitvator at 7 weeks, and the Plasson Easy Start at 8 weeks. The Lubing EasyLine™ and the ValCo Turkey Drinker were left for the duration of the project at the request of those companies.

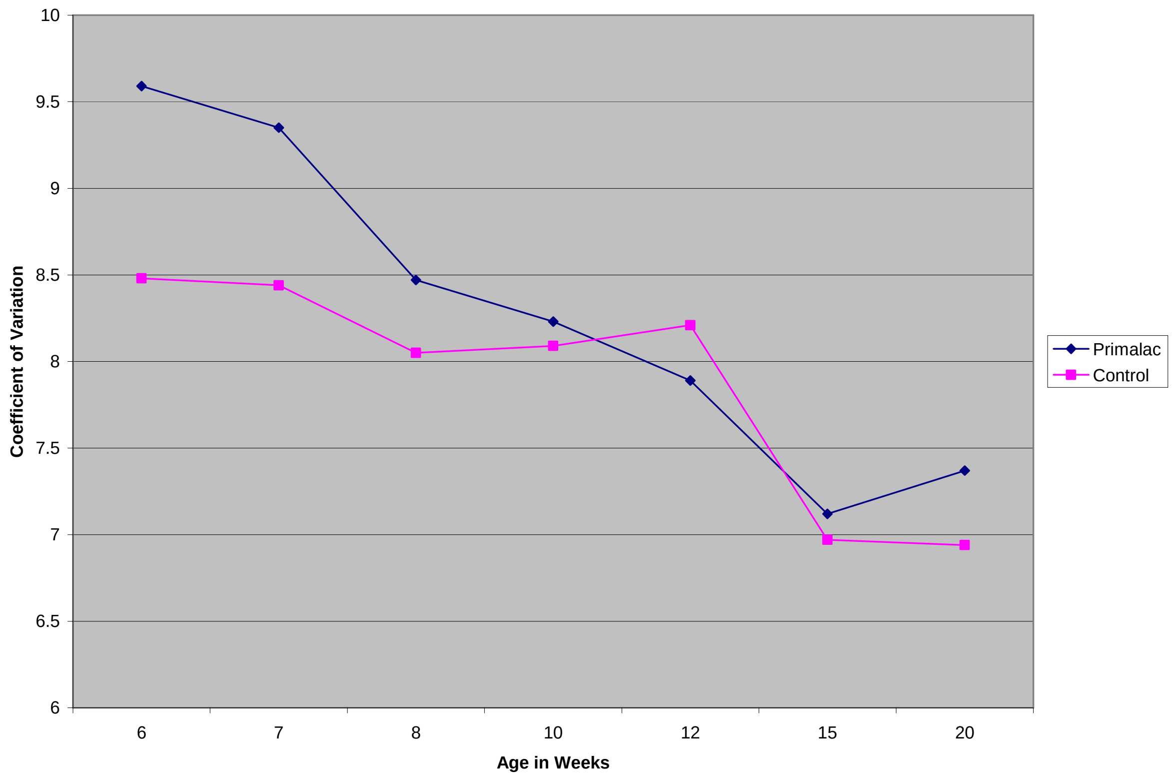

Figure 3. Coefficient of variation[1] of body weight of Large White commercial turkey males reared on different feed treatments[2] from six to twenty weeks.

[1] There are no significant differences at any data point (SEM=0.43).
[2] Birds were fed diets with and without the direct-fed microbial PrimaLac® (Star Labs, Clarksdale, MO).

Manusricpt II: The Efficacy of Nipple Drinkers and a Direct-Fed Microbial on the Performance of Large White Commercial Turkey Females

ABSTRACT

Public concern over the use of dietary antibiotics in food animal production is increasing. With this, the growing environment as well as alternatives to dietary antibiotics are under increased scrutiny. In the turkey industry, the use of nipple drinkers is being studied to enhance the growing environment and direct-fed microbials are being examined. The objective of this study was to test the efficacy of nipple drinkers and a direct-fed microbial on turkey performance. A 2 by 6 factorial design was used (6 drinker types & 2 feed treatments). The drinker treatments were: 1) control Plasson Minibell, 2) Plasson Easy Start, 3) Lubing Traditional (FeatherSoft® high flow nipple with Littergard®), 4) Lubing EasyLine™, 5) ValCo Turkey Drinker, and 6) Ziggity, BigZ Activator. All drinkers remained in use through the duration of the trail except the Lubing Traditional which was changed to the Plasson Bell at 6 weeks of age and the Ziggity, Big-Z Activator which had to be changed to the Plasson Bell at 14 weeks of age. Typical turkey diets were formulated with and without the direct-fed microbial PrimaLac® (Star Labs, Clarksdale, MO).

In experiment 1, fourteen-hundred and forty (30/pen) commercial Large White Hybrid Converter® (Kitchener ON, Canada) hens were reared to 3 weeks of age. Partitions were used to increase brooding density and were removed for the grow-out period. These methods were also used in experiment 2; feed consumption, by pen, and BW were measured at 1, 3, 5-6, 8, 10, 12, 14, 16, and 18 weeks. Feed conversion ratio (FC) was calculated at each measurement for each trial. Data were analyzed in each trial

using the General Linear Model procedure of SAS, Inc., using the least square (LS) Mean procedure to separate treatment means ($p \leq 0.05$). There were no feed by drinker type interactions in any trial.

In experiment 1, there was significant mortality by both strain and drinker type with the most significant mortality seen in strain A and Lubing EasyLine™ drinker. In the second experiment, 6 week body weights of birds reared on the Plasson Bell and ValCo Turkey Drinker were higher than birds reared on the Plasson Easy Start and Ziggity, Big-Z Activator with the Lubing EasyLine™ being intermediate. The Lubing Traditional Nipple yielded lower body weights at 6 weeks of age than did all other drinker types. By 16 weeks of age, there were no longer any significant differences in body weight by drinker type. Body weight was heavier for birds fed PrimaLac® through 8 weeks of age. Cumulative feed conversion was significantly improved for birds reared on direct-fed microbial through 8 weeks of age. The results of this study show that some nipple drinker systems are effective at least through the brooding period for turkeys with some systems being capable of carrying birds through to market. The direct-fed microbial used herein is a viable alternative candidate to dietary antibiotics for rearing turkeys. Further research, comparing a direct-fed microbial to an antibiotic growth promoter, is needed to ascertain the true viability of direct-fed microbial products.

INTRODUCTION

The United States poultry industry is currently taking advantage of all possible areas that can be enhanced for more efficient production (Michel, et al., 1998). Recent public controversy over the use of dietary antibiotics in animal production has forced the industry to focus on creating the healthiest production conditions possible (Watkins, 2002). Specifically, the turkey industry is currently interested in using new drinker technology as a way to enhance the production environment and improve production efficiency. In addition, direct-fed microbials are currently being examined as an alternative to antibiotic growth promoters.

Nipple drinkers became the predominant drinker of the broiler industry in the late 1980's, replacing the conventional Bell drinker (Wabeck, Carr, and Byrd, 1994). The turkey industry is seeking to capitalize on the success experienced by the broiler industry. Nipple drinkers are reported to improve overall flock health by delivering fresh, uncontaminated drinking water and reducing water spillage, which in turn yields drier litter carrying reduced pathogen load (Wabeck, Carr, and Byrd, 1994). While nipple drinkers have delivered consistently lower body weights in research trials (Brown, et al., 1995), most studies agree that birds raised on nipple drinkers have improved feed conversion as compared to birds reared on conventional drinkers. There is field data that suggests that broilers raised on nipple drinkers had similar body weights to those raised on conventional drinkers (Brown, et al., 1995). Lee and Zimmerman concluded that the benefits of using nipple drinkers outweigh the loss in body weight yielded by the waterer.

The benefits of antibiotic growth promoters were first noted in 1946 by Moore, et al. (1946). These growth promoters have been used in the United States and elsewhere since their discovery (Dibner and Richards, 2005), but recently, the use of these growth promoters has come under increasing investigation leading to a ban on their use in the European Union. Their use is also being scrutinized in the United States due to increased public pressure and shifting consumer preferences toward products that have not been treated with antibiotics and other chemicals. While antibiotic resistance is increasing, there is no evidence that the subtherapeutic antibiotic use in animal agriculture is a threat to human health (Bywater, 2005).

With increasing public concern, the poultry industry is investigating several alternatives to antibiotic growth promoters. Joerger (2003) reported the experimental investigation of alternatives such as bacteriophages, bacteriocins, serum therapy, and antimicrobial peptides, but these alternatives do not seem viable for the immediate future. Enzymes and Organic acids have been used as alternatives in the field with limited success. Currently, the focus of most alternative research is in the area of prebiotics and probiotics or direct-fed microbials. The purpose of these studies was to examine the effectiveness of nipples drinkers and the direct-fed microbial PrimaLac® in production, evaluate their affect on the performance of commercial turkey males, and note the effect of the direct-fed microbial on birds that may experience water restriction as a result of being reared on nipple drinkers.

MATERIALS AND METHODS

In experiment 1, fourteen-hundred and forty hens were reared to 3 weeks of age. A 2 x 6 x 2 factorial randomized block design was used with 2 feed treatments, 6 drinker types, and 2 hen strains (A and B). Thirty poults placed in each of the 48 pens. The treatments were randomly assigned to 2 halls of 24 pens each. The halls served as experimental blocks to account for variability within house. No supplemental jug drinkers were used in this trial. Body weight and feed consumption were measured by pen at placement and 3 weeks of age. Feed consumption was measured by pen and was calculated on a period and cumulative basis both by pen and averaged individual consumption. Period and cumulative feed conversion were calculated using the body weight and feed consumption data. Litter moisture was not measured in this trial because of its limited duration. Data were analyzed using the GLM Procedure of SAS.V8, Inc. The LS Mean procedure was used to separate treatment means ($p \leq 0.05$).

In experiment 2, fourteen-hundred and forty commercial Large White Hybrid Converter® (Kitchener ON, Canada) hens were reared to 18 weeks of age. There were 30 poults placed in each of the 48 pens. A 2 x 6 x 2 factorial randomized block design was used with 2 feed treatments, 6 drinker types, and 2 supplemental jugs treatments. The treatments were randomly assigned to 2 halls of 24 pens each. The halls served as experimental blocks to account for any effect of pen location within house. Each of the two diet and jug treatments had 24 replications, and each of the drinker treatments had 8 replications.

The feed for both experiments was commercially manufactured and the diets were typical of those commonly used in turkey production formulated with and without the direct fed microbial PrimaLac®. Samples of all feed batches were analyzed by an independent lab (Star Labs/Forage Research, Clearwater, FL) to ensure the presence of PrimaLac® in treated feeds and the absence of PrimaLac® in control feeds. PrimaLac® is a direct-fed microbial that contains *Lactobacillus acidophilus, Lactobacillus casei, Bifidobacterium bifdium,* and *Enterococcus faecium*. This product and its culture remain viable through the pelleting process. PrimaLac® contains a minimum of 1.0×10^8 CFU of *Lactobacillus* organisms per gram.

The control drinker was the conventional bell drinker – the Plasson Mini-Bell (Diversified Imports, Maagan Micheal DN Mensashe, Israel) during brooding and the Plasson Turkey Bell (Diversified Imports, Maagan Micheal DN Mensashe, Israel) during the grow-out period. There were five nipple drinker systems tested and compared to the control: Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel), ValCo Turkey Drinker (Val-Co, Lancaster, PA), Lubing Traditional (FeatherSoft® high flow nipple with Littergard®)(Lubing, Cleveland, TN), Lubing EasyLine™(Lubing, Cleveland, TN), and Ziggity Big-Z Activator (Ziggity Systems, Inc., Middlebury, IN). All nipples were on six-foot sections in each individual pen. The Plasson easy start had two cups per six-foot line. The ValCo Turkey Drinker and the Lubing EasyLine™ had two cups per six foot line. The Lubing EasyLine™ required a brooding ball to be placed in the cup for the first 2 weeks to allow for easier water access for the poults. The Lubing Traditional (FeatherSoft® high flow nipple with Littergard®) had four nipples per six-foot line. The Ziggity Big-Z Activatior had five nipples per line. In experiment 2, supplemental jug drinkers were used in half the pens, randomized evenly over all treatments, until one week of age. In experiment 2, all of the nipples remained until at least 6 weeks of age to simulate commercial brooding duration. The Lubing Traditional nipple was changed at 6 weeks to the Plasson Turkey Bell. All other drinkers were intended to remain throughout the trial, but the Ziggity drinker was changed at 14 weeks when the mean body weights of those birds became significantly less than the body weights of those birds on all other drinkers.

The facility used for these experiments was a curtain-sided house, which contained 48 concrete floored pens that were 2.44m by 2.44m (5.95m^2). To simulate commercial brooding densities, wire mesh was used to partition the pens to 1.52m by 2.44 or 3.72m^2. The wire mesh was removed at 5 weeks in experiment 2 to simulate the time when turkeys are typically moved to grow-out facilities in commercial growing conditions. Pen floors were covered with clean wood-shavings. Cake was removed and weighed throughout the trial as necessary with clean shavings added to supplement cake removed when needed. Four mixing fans in placed throughout each hallway served to mix natural air that was regulated by carefully adjusted side curtains. Supplemental gas-heaters in each hall along with heat lamps in each pen were used to heat the house during brooding. Feed and water were provided *ad libitum* throughout the entire trial. Lighting was continuous for the first 24 hours and by natural daylight thereafter (except that light which was provided when the heat lamps were in use). A shade curtain was added to the southeast side of the house in an attempt to equalize temperatures throughout the house. House temperature was kept between 88°F and 94°F for the first 10 days and was then gradually decreased by 5°F each week to ambient temperature. High and low house temperatures were recorded twice daily in four locations throughout the house for the entire length of these experiments.

Special precautions were taken in order to ensure that feed treatments remained separated and control pens remained uncontaminated. Feed was delivered to the same bulk bins each time and separate augers were used for each bin. The feed was stored in 1000 lb feed carts for hand feeding with lids on the boxes to prevent dust contamination. Each feed treatment had designated buckets used for feeding. Twenty-four inch wooden partitions were built around the perimeter of each pen as a physical barrier to contamination. All work, including feed weighing and maintenance was done in control pens first. Tools, such as shovels and pitch-forks, were also specific to feed treatment. When working in treated pens, boots were worn and removed upon exiting the pen. Farm staff washed and sanitized their hands after working in treated pens. The concrete hallways were washed after work was complete in treated pens and were washed again before work began in control pens.

In experiment 2, body weight and feed consumption were measured at weeks 1, 3, 5, 6, 8, 10, 12, 14, 16, and 18. Body weights were measured by pen at the 3 and 5 weeks and individually at all subsequent measurement dates. Feed consumption was determined by pen at each weigh day. Period and cumulative feed conversion were calculated using the body weight and feed consumption data and was expressed per bird. Period feed conversion was calculated as a feed:gain ratio for that period. Cumulative feed conversion was calculated using total weight and total feed consumed. Mortality and culled birds were recorded as they occurred, and their weights were used to adjust feed conversion. Litter moisture was measured beneath the drinker and representatively by pen at placement, 1-4 weeks, and 6 weeks. Cake removed was weighed and analyzed cumulatively and by period each week until the end of the trail. Samples were taken from the composite, weighed, and dried for no less than 24 hours. A second weight was recorded after the drying period. These weights were used to calculate percent moisture based on the following equation:

$$[(\text{Sample Weight 1} - \text{Sample Weight 2})/\text{Sample Weight 1}] \times 100 = \%\ \text{Moisture}$$

Fresh fecal samples were analyzed to enumerate coliform bacteria in each sample using the procedure described in the FDA Bacteriological Analytical Manual. These samples were also checked for the presence of S*almonella* using the procedure outlined in Chapter 4 of the USDA Microbiology Laboratory Guidebook.

Data were analyzed using the GLM Procedure of SAS.V8, Inc. The LS Means procedure was used to separate treatment means ($p \leq 0.05$). The pen served as the experimental unit for all performance data.

RESULTS

Experiment 1

Mortality by strain and drinker type for hens from placement to 3 weeks of age was significant but without interaction (Table 1). Strain A showed significantly greater mortality than Strain B on all drinker types (Table 2). By drinker type, significantly higher mortality was observed in the birds brooded on the Lubing EasyLine™ drinkers compared to all other drinker types. There were no significant differences in mortality by feed treatment (Table 3).

Experiment 2

No effect of supplemental drinkers was seen at 1 week of age (BW with supplemental drinkers 152g±1g and without supplemental drinkers 151±1g). During the brooding period was 2% with 95% livability for the entire trial excluding 3% culls, and mortality was not significant at any point. There were no differences in body weight at placement due to treatment (52±1g) (Table 4). At one week of age, there were no differences in body weight by drinker type. At 3 weeks of age, only the body weights of birds reared on the Lubing Traditional Nipple (0.545±0.005kg) were different from the body weights of those birds reared on the Plasson Bell (0.572±0.005kg). This pattern was also observed at 5 weeks. At 6 weeks of age, the birds reared on the Plasson Easy Start (1.99±0.01kg) and the Ziggity, Big-Z Activator (1.97±0.01kg) had reduced body weights compared to the birds grown on the Plasson Bell (2.04±0.01kg) with the Lubing

EasyLine^{TM} being intermediate. At 6 weeks of age, the body weights of the birds grown on the Lubing Traditional Nipple were lower than the body weights of birds reared on all other drinkers. Body weights from 8 to 18 weeks of age are shown in Table 5. Eight week body weights follow the same pattern as 6 week body weights. By 10 weeks of age, the birds raised on the Plasson Easy Start (5.09±0.03kg) had significantly lower body weights compared to birds raised on the control drinker (5.20±0.03kg). The ValCo Turkey Drinker was intermediate with the body weights of birds reared on the Lubing Traditional Nipple (4.96±0.03kg) and the Ziggity, Big-Z Activator (4.98±0.03kg) being significantly lower than the body weight of birds grown on all other drinkers. At 12 weeks of age, the body weights of those birds reared on the Plasson Easy Start (6.28±0.04kg) and the Lubing Traditional Nipple were lower than the body weight of the birds raised on the control drinker (6.45±0.04kg). The body weights of birds on the Ziggity, Big-Z Activator (6.15±0.04kg) were reduced compared to the body weights of birds reared on all other drinkers at 12 weeks of age. At 14 weeks of age, only the body weights of the birds reared on the Ziggity, Big-Z Activator (7.57±0.05) were lower compared to the body weights of birds on the Plasson Bell (7.89±0.05). At this point, these birds were switched from the Ziggity, Big-Z Activator to the Plasson Bell because of severe water restriction. At 16 and 18 weeks of age, there were no significant differences in body weight due to drinker type.

Body weights for the brooding period by feed treatment are shown in Table 6. From placement to six weeks of age, body weights of those birds being fed the direct-fed microbial was greater than the body weights of the control birds. At 6 weeks of age, birds fed the direct-fed microbial weighed 2.00±0.01kg compared to the birds fed control feed (1.93±0.001kg). Body weights by feed treatment from 8 to 18 weeks of age are presented in Table 7. Birds fed the direct-fed microbial continued to be heavier through eight weeks of age, but this difference was no longer significant at 10 weeks of age. There was a significant difference in body weight at 12 weeks of age with the birds being fed the direct-fed microbial (6.36±0.02kg) having significantly greater body weights compared to birds fed the control diet (6.29±0.02kg). There was no significant difference in body weight by feed treatment from 14 weeks through the end of the trail.

Cumulative feed conversion by drinker type from 1 week of age to 6 weeks of age is shown in Table 8. Cumulative feed conversion was not significant by drinker type through the brooding period from 1 to 6 weeks of age. Cumulative feed conversion by drinker type from 8 weeks of age to 18 weeks of age is presented in Table 9. During the growing period, cumulative feed conversion was significant at 8 weeks with the birds reared on the Lubing Traditional Nipple (1.35±0.01) having significantly improved feed conversion compared to birds raised on all other drinker types. There were no significant differences in cumulative feed conversion from 10 to 14 weeks. At 16 weeks, the birds reared on the Plasson Bell (2.56±0.03), Plasson Easy Start, and the Ziggity, Big-Z Activator had improved feed conversion with the birds reared on the Lubing EasyLine™ (2.71±0.03) being the least efficient and the birds raised on the Lubing Tradional Nipple and ValCo Turkey Drinker being intermediate. There were no differences in cumulative feed conversion by drinker type at 18 weeks of age.

Cumulative feed conversion was improved for birds being fed the direct-fed microbial throughout the brooding period from 1 to 6 weeks (Figure 1). At 8 weeks, the birds being fed the direct-fed microbial (1.39±0.01) also exhibited significantly improved feed conversion compared to the birds fed the control diet (1.41±0.01) (Table 10). There were no differences in cumulative feed conversion by feed treatment from 10 weeks of age to the end of the trial.

Cumulative feed consumption (kg/bird) for the brooding period by drinker type. Cumulative feed consumption was not significantly different for birds reared on any drinker type at 1 week of age (Table 11). At 3 weeks of age, birds reared on the Lubing EasyLine™ (0.345±0.010kg), ValCo Turkey Drinker, and the Ziggity, Big-Z Activator had significantly higher feed consumption than the birds reared on the Plasson Easy Start (0.328±0.010kg). Birds reared on the Lubing Traditional Nipple (0.297±0.010kg) had significantly lower feed consumption than did birds on all other drinker types with the feed consumption of birds reared on the Plasson Bell being intermediate. Cumulative feed consumption followed trends similar to those seen in body weight throughout the growing period (Table 12). Cumulative feed consumption by feed treatment is presented in Table 13 for the brooding period and Table 14 for the growing period. Cumulative feed consumption was significantly higher for the control birds at 1 and 3 weeks of age. There were no significant differences in feed consumption by feed treatment from 5 to 18 weeks.

Litter moisture (%) by pen by drinker type during the brooding period is presented in Figure 2. Litter moisture (%) per pen steadily increased through the brooding period, but was not significantly different by drinker type through 6 weeks of age. There were no differences in litter moisture per pen by feed treatment recorded for the brooding period (Figure 3).

Litter moisture (%) beneath the drinker was not significant at 1 week of age (Table 15). At 2 weeks of age, litter moisture beneath the drinker was lower beneath the Lubing Traditional Nipples (15.35%±1.97%), ValCo Turkey Drinkers, and the Ziggity, Big-Z Activators compared to the Plasson Bell (22.14%±1.97%) with the Lubing EasyLine™ and the Plasson Easy Start being intermediate. All nipple drinker systems had lower litter moisture beneath the drinker at 3 weeks of age compared to the Plasson Bell (35.71%±2.18%). By 4 weeks of age, only the Lubing Traditional Nipple (41.92%±4.94%) and the Ziggity, Big-Z Activator had lower litter moisture beneath the drinker compared to the control drinker (60.92%±4.94%) with the Lubing EasyLine™ being intermediate. At the end of the brooding period, the Plasson Easy Start (65.63%±4.03%) had higher litter moisture beneath the drinker compared all other drinkers except the Lubing EasyLine™ which was intermediate. Litter moisture beneath the drinker by feed treatment during the brooding period is presented in Figure 4. Litter moisture (%) beneath the drinker was not significant by feed treatment at any point during the brooding period.

Litter cake in pens was not significant for any drinker type at 9 weeks of age (Table 16). At 12 weeks of age, the Lubing Traditional Nipple (17.79±13.66kg) and Ziggity, Big-Z Activator pens had less litter cake than did the Plasson Bell (65.04±13.66kg), Plasson Easy Start, or Lubing EasyLine™ with the ValCo Turkey Drinker being intermediate. There were no differences in litter cake at 18 weeks. Cumulatively, the Plasson Bell (153.98±17.83kg) and Plasson Easy Start pens had significantly increased litter cake with the Lubing Traditional Nipple (103.21±17.83kg) being significantly less and the Lubing EasyLine™ and ValCo Turkey Drinker being intermediate. The Ziggity, Big-Z Activator (41.75±17.83kg) yielded significantly less litter cake compared to all other drinker types. There were no differences in litter cake by feed treatment (Figure 5).

The coefficient of variation of body weight by drinker type, followed a similar trend for all drinkers throughout the trial (Figure 6). Coefficient of variation of body weights continuously decreased from 5 to 18 weeks of age, with the range from highest coefficient of variation and lowest coefficient of variation narrowing as the birds aged. There were no differences in coefficient of variation by drinker type at any age. This decreasing trend was also seen by feed treatment (Figure 7). There were no differences in coefficient of variation of body weight at any measurement by feed treatment, and the margin between the two treatments narrowed at the birds aged.

DISCUSSION

The current controversy over the use of dietary subtherapeutic antibiotics as growth promoters has forced food animal industries to examine all aspects of the production environment to reduce the need for such growth promoters. Nipple drinkers have been the predominant drinker type in the broiler industry for over a decade. There are many advantages to using these drinkers including improved feed conversion, clean, less contaminated drinking water, reduced water spillage which yields drier litter and an overall reduced pathogen load. Reduced pathogen load in the litter not only aids in creating a more sanitary environment, but can also yield an overall healthier bird (Branton et al., 2001).

There are very little data on the use of nipple drinkers for turkey rearing, and their use in turkey production has shown mixed results, similar to those seen in broiler production. Hulet (1999) found that nipple drinkers were effective for brooding turkeys and could be used through 10 weeks of age successfully. The results of experiment 2 showed reduced body weights of those birds reared on nipple drinkers compared to birds reared on the conventional bell-type drinker, but these birds also had improved feed conversion compared to birds grown on conventional waterers. In a field trial by Rives (2001), body weights are reduced at the end of the brooding period, but seem to equalize by 10-12 weeks when up back on the bell drinker for the grow-out phase. Both experiment 2 and the Rives (2001) field trial concluded that a combination of closed watering systems for brooding and open watering systems for growing may be optimal for performance. For example: in experiment 2, birds brooded on the Plasson Easy Start and Ziggity, Big-Z Activator were changed to the Plasson Bell for the grow-out period. These birds showed equal performance to the control birds by the end of the study. However, this study did note that some systems, like the Lubing EasyLine™, are capable of carrying birds through to market age with similar comparable performance to the controls.

It is generally accepted that birds reared on nipple drinkers yield decreased body weights, improved feed conversion, and improved bird health. In a research trial by Hulet (1999), it was noted that the many advantages of nipple drinkers could offset the disadvantageous reduction in body weight. Lee and Zimmerman (1987) concluded that the benefits of nipple drinkers outweighed the decreased body weight seen in broilers. There are many reports that note improved feed conversion of birds reared on nipple drinkers (Wabeck et al., 1994; Carpenter et al., 1990; Brown et al., 1995).

Practically, nipple drinkers need less cleaning and maintenance than do conventional drinkers which provides growers with labor savings. These systems also make it easier to administer vaccinations and medications through the water while reducing wastage because of water spillage. The caveat to these systems is that they do require more intense management than do conventional open-watering systems, and producers must be more knowledgeable to properly manage these drinker systems (Tabler, 2003). In the first experiment, there was significant mortality reported by both strain and drinker type, particularly in the Lubing EasyLine™ drinker. This drinker requires a brooding ball to raise the water level in the drinker for the first few days to give the poults more opportunity to find the water and learn to use the drinker. As seen in experiment 1, significant mortality can occur if the drinkers are not used properly.

Experiment 2, like the Rives (2001) field trial, showed that birds experienced apparent compensatory growth when put back on the Plasson Turkey Bell. True compensatory is not seen in actual growing conditions because if birds were growing at maximum genetic potential, there would not be an opportunity for true compensatory growth to occur. It is commonly assumed that optimum growing conditions yield optimum growth, but this does not necessarily equal 100% of genetic potential. If one assumes that water consumption generally drives feed consumption which in turn drives growth rate, then nipple drinkers that limit water consumption ultimately limit growth rate. Apparent compensatory growth is observed under the assumption that the control birds were not growing at 100% of genetic potential, which gave the water restricted birds an opportunity to match the body weight of the control birds when given access to adequate amounts of water. When significant differences between drinker types initially disappeared in experiment 2, it seemed as though this was only a statistical anomaly and not a biological response given the increases noted in SEM. However, by week 16, it was apparent that the birds that had been water restricted by the nipple drinkers did recover in body weight when that restriction was removed. By the end of experiment 2, there were no differences in body weight by drinker type. Even those birds that had been severely water restricted showed apparent compensatory growth when put back on open-waterers and were not longer water restricted.

This differs from the results in the stated in Manuscript I, but only at the end of the trial. The differences due to drinker type remained in both trials through 12 weeks of age. If the study discussed herein were stopped at an earlier time, similar results would have been seen. It should also be noted that both the study herein and the study discussed in Manuscript I were carried out during different seasonal conditions therefore changing the growing conditions for the birds at similar ages.

Direct-fed microbial research is currently focusing on finding beneficial dietary microbes that are viable in the commercial production environment. Promoting the growth of these microbes is essential since some of them are not naturally occurring in the gut. Beneficial bacteria in the gut are capable of improving feed efficiency by increasing nutrient absorption (Solis de los Santos et al., 2005). There are said to be four major mechanisms for competitive exclusion in the gut including competition for receptive binding sites, production and secretion of compounds toxic to other microbes, competition for nutrients, as well as generally making the gut environment inhospitable to other microbes (Rolfe, 1991). These products must have high adhesion ability to epithelial cells of the crop and the intestines (Reid and Friendship, 2002). Edens, et al.

(1997) noted that the colonization of lactic acid producing bacteria in the gut of chickens and turkeys has been shown to have beneficial effects particularly related to the production of bacteriocins by these bacteria.

Studies of direct-fed microbials have reported inconsistent results. It should be noted that some variation in the results can be attributed to differences in bacterial species used in the specific cultures tested or the methods used in preparing the cultures (Jin et al., 1998). In reviewing reports on direct-fed microbial studies, the possibility of cross-contamination between the direct-fed microbial treatments and the control fed birds must be considered. If contamination of control birds occurs, the treatment affect can be lost. England et al. (1996) noted contamination of control birds from across an isle during *Bacillus subtilis* a feeding study. In later studies, England et al. (1996) reportedly took extensive measures to prevent contamination of control birds. These measures are supported by observations and efforts made by Tortuero (1973), Watkins and Miller (1983a), Watkins and Miller (1983b), and Fritts et al. (2000) using chicks in similar studies. In the current experiments, there were also special precautions taken in an attempt to ensure that cross-contamination did not occur. In any study testing the effect of direct-fed microbials, unless the author describes the methods used to prevent cross-contamination, the results must be viewed with caution particularly if no effect was reported.

Carlson et al. (1979) showed no effect on body weight or feed conversion of feeding direct-fed microbials to tom turkeys to 24 weeks of age in early reports. Owings (1992) found no effect of feeding probiotics on body weight, but reported an improvement in feed conversion with the addition of probiotics to the diet even beyond the improvements noted as a result of the antibiotic treatment in that study. This is similar to the results seen in experiment 2 in that while there was no difference in body weight at 18 weeks, feed conversion was significantly improved for birds fed direct-fed microbial through 8 weeks of age. Other studies confirm the findings of Owings (1992) and concur that feeding a dietary probiotic can result in improve feed conversion (Jiraphocakul et al., 1990; Jin et al., 1998; Zulkifli et al., 2000; Fritts et al., 2000). Potter et al. (1979) reported that birds fed *Lactobacillus acidophilus* were heavier than controls at 8, 10, and 12 weeks of age, but found no effect on feed conversion. In experiment 2, there was a difference in body weight between birds fed the direct-fed microbial with birds fed the direct-fed microbial being heavier than controls though 12 weeks of age, but not thereafter.

While any explanation of the mode of action of direct-fed microbials is beyond the scope of these studies, McCracken and Gaskins (1999) propose that the bacteria that naturally occur in the gut compete with their host for nutrients, secrete toxic compounds, and can cause on-going inflammatory immune responses in the gut. Direct-fed microbial products also have high adhesion ability to epithelial cells of the crop and intestines (Reid and Friendship, 2002), and are said to enhance the mucosal layer that covers the intestinal surfaces (Fuller, 1989).

Further research is needed to ascertain of how nipple drinkers affect the performance of commercial turkeys. This is particularly important under field conditions. Because research in rearing commercial turkeys on nipple drinkers is so limited, there is a great need for further research in all areas of this expanding field of study. Additionally, with respect to direct-fed microbials, further research is needed to better understand how direct-fed microbials interact with other feed ingredients and feed additives. Since certain direct-fed microbials have been shown to survive commercial milling processes such as pelleting, additional testing of direct-fed microbials is needed, particularly under field conditions.

CONCLUSIONS

From the results of this study, it can be concluded that some nipple drinkers systems are effective through the brooding period for turkeys with some systems being capable of supporting adequate growth of birds through to market age. With hens, it seems that most nipple drinker systems can produce comparable performance to conventional drinkers, including body weight. While nipple drinkers generally yield numerically reduced market body weights, the significant improvement in feed conversion and litter moisture may outweigh the effects of decreased body weights. Litter moisture can be significantly reduced with the use of nipple drinkers if managed properly during rearing. But to benefit from the use of nipple drinkers, these systems must be properly managed because significant mortality can occur as a result of mismanagement particularly in the first few days of brooding. The direct-fed microbial used in this study yielded increased body weights through 12 weeks of age and significantly improved feed conversion throughout the entire length of the trial. However, the effect of the direct-fed microbial was seen universally with no added effect for birds that experienced reduced growth as a result of being reared on a nipple drinker. Therefore, the direct-fed microbial used herein is a viable alternative candidate to dietary antibiotics for rearing turkeys. Further research, comparing a direct-fed microbial to an antibiotic growth promoter, is needed to ascertain the true viability of direct-fed microbial products.

REFERENCES

Anonymous, 1998. Chapter 4: Isolation and Identification of *Salmonella* from Meat, Poultry and Egg Products. Pages 4:1-14 in USDA/FSIS Microbiology Laboratory Guidebook. 3rd ed. Volume 1. US Government Printing Office, Washington, D.C.

Branton, S. L., J. D. Simmons, B. D. Lott, and D. M. Miles, 2001. Chick Mortality Associated with Elevated Water Lines and Consumption of Wet Litter. J. Appl. Poult. Res. 10: 427-430.

Brown, T.M., M.M. Beck, D.D. Schulte, D.D. Jones, J.H. Douglas, and S.E. Scheideler, 1995. Nipple Waterers for Chick Batteries: Design, Efficiency, and cost Analysis. Poultry Sci. 74: 457-462.

Bywater, R. J., 2005. Identification and Surveillance of Antimicrobial Resistance Dissemination in Animal Production. Poultry Sci. 84: 644-648.

Carlson, C. W., R. A. Nelson, and A. B. Kashani, 1979. Effects of probiotics on turkeys and laying hens. Pages 18-20 in: Proceedings of the 11th South Dakota State University Poultry Day, Brookings, SD.

Carpenter, G. H., R. A. Peterson, and W. T. Jones, 1990. Effects of the Presence or Absence of Satellite Chick-Waterers in Conjunction with Nipple-Drinkers on the Mortality and Productive Performance of Broiler Chicks from Young and Old Dams. Poultry Sci. 69: 45-47.

Dibner, J. J. and J. D. Richards, 2005. Antibiotic Growth Promoters in Agriculture: History and Mode of Action. Poultry Sci. 84: 634-643.

Edens, F. W., C. R. Parkhurst, I. A. Casas, and W. J. Dobrogosz, 1997. Principles of *Ex Ovo* Competative Exclusion and *In Ovo* Administration of *Lactobacillus reuteri*. Poultry Sci. 76: 179-196.

England, J. A., S. E. Watkins, Emad Saleh, and P. W. Waldroup, 1996. Effects of *Lactobacillus reuteri* on Live Performance and Intestinal Development of Male Turkeys. J. Appl. Poultry res. 5: 311-324.

Feng, P., S. D. Weagant, and M.A. Grant, 1998. Chapter 4: Enumeration of *Escherichia coli* and the Coliform Bacteria. Pages 4.01-4.29 in the Food and Drug Administration Bacteriological Analytical Manual. 8th ed. Rev.A. AOAC International, Gaithersburg, MD.

Fritts, C. A., J. H. Dersey, M. A. Motl, E. C. Kroger, F. Yan, J. Si, Q. Jiang, M. M. Campos, A. L. Waldroup, and P. W. Waldroup, 2000. *Bacillus Subtilis* C-3102 (Calsporin) Improves Live Performance and Mcirobiological Status of Broiler Chickens. J. Appl. Poultry Res. 9: 149-155.

Fuller, R., 1989. Probiotics in man and animals. J. Appl. Bacteriol. 66: 365-378.

Jin, L. Z., Y. W. Ho, N. Abdullah, and S. Jalaludin, 1998. Growth Performance, Intestinal Microbial Populations, and Serum Cholesterol of Broilers Fed Diets Containing *Lactobacillus* Cultures. Poultry Sci. 77: 1259-1265.

Jiraphocakul, Saartchit, T.W. Sullivan, and K. M. Shahani, 1990. Influence of a Dried *Bacillus subtilis* culture and Antibiotics on Performance and Intestinal Microflora in Turkeys. Poultry Sci. 69: 1966-1973.

Joerger, R. D., 2003. Alternatives to Antibiotics: Bacteriocins, Antimicrobial Peptides and Bacteriophages. Poultry Sci. 82: 640-647.

Lee, S.R. and N.G. Zimmerman, 1987. Effects of Enclosed Nipple Drinkers vs Dome Waterers on Broiler Performance. Poultry Sci. (Suppl.) 66: 132.

McCracken, V. J. and H. R. Gaskins, 1999. Probiotics and the immune system. Pages 85-111 in Probiotics: A critical review. G. W. Tannock, ed. Horizon Scientific Press, Norfolk, UK.

Michel, K., C. Gempesaw, J. Pesek, J. Bacon, and H. Tilmon, 1998. Drinker Technology as an Example of Improving Production Efficiency. J. Appl. Poultry Res. 7: 144-151.

Moore, P. R., A. Evanson, T. D. Luckey, E. McCoy, C. A. Elvehjen, and E. B. Hart, 1946. Use of sulfasuxidine, streptothricin, and streptomycinin nutritional studies with the chick. J. Biol. Chem. 165: 437-441.

Owings, W. J., 1992. Research Note: Nutritive Effects of a Direct-Fed Microbial Preparation on Growing Turkey Toms. Poultry Sci. 71: 932-935.

Potter, L. M., L. A. Nweborn, C. M. Parsons, J. R. Shelton, and J. S. Crawford, 1979. Effects of protein, poultry by-product meal, and dry *Lactobacillus acidophilus* culture additions to diets of growing turkeys. Poultry Sci. 58: 1095 (abstract).

Reid, G. and R. Friendship, 2002. Alternatives to Antibiotic Use: Probiotics for the Gut. Animal Biotechnology. 13(1): 97-112.

Rolfe, R. D., 1991. Population dynamics of the intestinal tract. Pages 59-75 in: Colonization Control of Human Bacterial Enteropathogens in Poultry. L.C. Blankenship, ed. Academic Press, Inc., San Diego, CA.

SAS Institute, 1992. SAS User's Guide. Version 6.08. SAS Institute, Inc., Cary, NC.

Solis de los Santos, F., M. B. Farnell, G. Téllez, J. M. Balog, N. B. Anthony, A. Torres-Rodreguez, S. Higgins, B. M. Hargis, and A. M. Donoghue, 2005. Effect of Prebiotic on Gut Development and Ascites Incidence of Broilers Reared in a Hypoxic Environment. Poultry Sci. 84: 1092-1100.

Tabler, Tom G., 2003. Nipple Drinker Management Critical to Broiler Performance. AVAIN Advice. 5(1): 9-12.

Tortuero, F., 1973. Infulence of the implantation of *Lactobacillus acidophilus* in chicks on the growth, feed utilization, malabsorptin of fats syndrome and intestinal flora. Poultry Sci. 52: 197-203.

Wabeck, Charles J., Lewis E. Carr, and Veronica Byrd, 1994. Broiler Drinker Systems and Seasonal Effects on Eviscerated Carcass and Leaf Fat Weights. J. Appl. Poultry Res. 3: 274-278.

Watkins, Susan, 2002. The Campaign for Quality Drinking Water Continues. AVIAN Advice. 4(3): 7-9.

Watkins, B. A., and B. F. Miller, 1983a. Competitive intestinal exclusion of avian pathogens by *Lactobacillus acidophilus* in gnotobiotic chicks. Poultry Sci. 62: 1772-1779.

Watkins, B. A., and B. F. Miller, 1983b. Colonization of *Lactobacillus acidophilus* in gnotobiotic chicks. Poultry Sci. 62: 2152-2157.

Zulkifli, I., N. Abdullah, N. Mohd. Azrin, and Y. W. Ho, 2000. Growth performance and immune response of two commercial broiler strains fed diets containing *Lactobacillus* cultures and oxytetracycline under heat stress conditions. British Poultry Science. 41: 593-597.

Experiment 1

Table 1. Effect of strain on percent mortality of Large White commercial turkey males brooded on drinker types[1] to three weeks of age.

	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Strain							
A	9.25	23.42	8.33	34.08	11.67	24.92	5.11
B	5.00	5.83	1.67	17.50	3.33	5.00	4.13
Mean	7.13^{bc}	14.63^{b}	5.00^{c}	25.79^{a}	7.50^{bc}	14.96^{b}	3.28

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

Table 2. Effect of strain on percent mortality of Large White commercial turkey males at three weeks of age.

	Strain A	Strain B	SEM
Age[1]			
3	18.61[a]	6.39[b]	1.81

[1] Age is in weeks and values reported are percentages.
[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 3. Effect of feed treatment on percent mortality of Large White commercial turkey males at three weeks of age.

	DFM[1]	Control	SEM
Age[2]			
3	13.17	11.83	1.84

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Age is in weeks and values reported are percentages.

Experiment 2

Table 4. Body weight of Large White commercial turkey females from placement to six weeks of age brooded on different drinker types[1].

	Industry Standard	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]								
0[4]		52	52	52	52	53	53	1
1[4]	180	149	153	151	153	151	150	2
3[5]	0.730	0.572^{a}	0.578^{a}	0.545^{b}	0.579^{a}	0.572^{a}	0.582^{a}	0.005
5[5]	1.71	1.47^{a}	1.48^{a}	1.32^{b}	1.46^{a}	1.48^{a}	1.46^{a}	0.01
6[5]	2.37	2.04^{a}	1.99^{b}	1.75^{c}	2.02^{ab}	2.04^{a}	1.97^{b}	0.01

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[3] Age 0 is day of hatch. Ages 1-6 are in weeks.

[4] Body weight in grams for day of hatch and 1 week.

[5] Body weight in kg for ages 3-6 weeks.

[a, b, c] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 5. Body weight of Large White commercial turkey females from eight weeks of age to market reared on different drinker types[1α].

	Industry Standard	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]								
8	3.95	3.57[a]	3.47[b]	3.25[c]	3.54[a]	3.52[a]	3.40[b]	0.03
10	5.69	5.20[a]	5.09[b]	4.96[c]	5.22[a]	5.17[ab]	4.98[c]	0.03
12	7.38	6.45[a]	6.28[b]	6.26[b]	6.45[a]	6.39[a]	6.15[c]	0.04
14	8.90	7.89[a]	7.78[a]	7.87[a]	7.85[a]	7.88[a]	7.57[b]	0.05
16	10.16	9.02	8.90	8.96	9.02	8.89	8.82	0.05
18	11.18	10.14	9.95	10.05	10.04	10.03	9.95	0.07

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[3] Ages 8-18 are in weeks and weights are measured in kg.

[a, b, c] Means within a row with different superscripts are significantly different ($p<0.05$).

[α] Except the Lubing Traditional Nipple which was changed to the Plasson Turkey Bell at 6weeks, all nipple drinkers remained in use for the duration of the project. The Ziggity, Big-Z Activator was changed to the Plasson Turkey Bell at 14 weeks when the body weights of those birds became significantly below all other drinker types.

Table 6. Body weight of Large White commercial turkey females from placement to six weeks of age reared on different feed treatments.

	Industry Standard	DFM[1]	Control	SEM
Age[2]				
0[3]		52	53	1
1[3]	180	156[a]	146[b]	1
3[4]	0.730	0.586[a]	0.557[b]	0.003
5[4]	1.71	1.47[a]	1.42[b]	0.01
6[4]	2.37	2.00[a]	1.93[b]	0.01

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Age 0 is day of hatch. Ages 1-6 are in weeks.
[3] Body weight in grams for day of hatch and 1 week of age.
[4] Body weight in kg for ages 3-6 weeks.
[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 7. Body weight of Large White commercial turkey females from eight weeks of age to market reared on different feed treatments.

	Industry Standard	DFM[1]	Control	SEM
Age[2]				
8	3.95	3.50[a]	3.42[b]	0.02
10	5.69	5.11	5.09	0.02
12	7.38	6.36[a]	6.29[b]	0.02
14	8.90	7.81	7.81	0.03
16	10.16	8.91	8.96	0.03
18	11.18	10.03	10.02	0.04

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Ages 8-18 are in weeks and body weights are measured in kg.
[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 8. Cumulative feed conversion of Large White commercial turkey females from placement to six weeks of age brooded on different drinker types[1].

	Industry Standard	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]								
1	1.16	0.85	0.87	0.86	0.87	0.88	0.93	0.02
3	1.30	0.78	0.80	0.78	0.83	0.82	0.83	0.02
5	1.41	1.20	1.21	1.22	1.24	1.22	1.22	0.01
6	1.48	1.18	1.19	1.14	1.20	1.18	1.21	0.02

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).
[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.
[3] Ages 1-6 are in weeks.

Table 9. Cumulative feed conversion of Large White commercial turkey females from eight weeks of age to market reared on different drinker types[1α].

	Industry Standard	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]								
8	1.62	1.40[a]	1.41[a]	1.35[b]	1.41[a]	1.41[a]	1.41[a]	0.01
10	1.78	1.56	1.56	1.50	1.55	1.56	1.53	0.02
12	1.96	1.95	1.95	1.89	1.94	1.92	1.89	0.02
14	2.17	2.24	2.23	2.20	2.25	2.20	2.16	0.03
16	2.39	2.56[b]	2.61[b]	2.62[ab]	2.71[a]	2.62[ab]	2.53[b]	0.03
18	2.64	2.73	2.79	2.79	2.86	2.80	2.75	0.04

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[3] Ages 8-18 are in weeks and weights are in kg.

[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

[α] Except the Lubing Traditional Nipple which was changed to the Plasson Turkey Bell at 6weeks, all nipple drinkers remained in use for the duration of the project. The Ziggity, Big-Z Activator was changed to the Plasson Turkey Bell at 14 weeks when the body weights of those birds became significantly below all other drinker types.

Table 10. Cumulative feed conversion of Large White commercial turkey females from eight weeks of age to market reared on different feed treatments[1].

Age[2]	Industry Standard	DFM[1]	Control	SEM
8	1.62	1.39[b]	1.41[a]	0.01
10	1.78	1.55	1.54	0.01
12	1.96	1.91	1.91	0.01
14	2.17	2.22	2.21	0.02
16	2.39	2.62	2.59	0.02
18	2.64	2.78	2.79	0.02

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Ages 8-18 are in weeks and body weights are measured in kg.
[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 11. Cumulative feed consumption (kg/bird) of Large White commercial turkey females from placement to six weeks of age brooded on different drinker types[1].

	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]							
1	0.127	0.134	0.131	0.133	0.134	0.139	0.004
3	0.316^{bc}	0.328^{b}	0.297^{c}	0.345^{a}	0.337^{a}	0.346^{a}	0.010
5	1.75^{a}	1.78^{a}	1.61^{b}	1.81^{a}	1.80^{a}	1.78^{a}	0.020
6	2.39^{a}	2.37^{a}	2.00^{b}	2.42^{a}	2.41^{a}	2.37^{a}	0.034

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).
[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.
[3] Ages 1-6 are in weeks and weights are in kg.
[a, b, c] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 12. Cumulative feed consumption (kg/bird) of Large White commercial turkey females from eight weeks of age to market reared on different drinker types[1α].

	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]							
8	5.01[a]	4.89[ab]	4.40[c]	5.01[a]	4.98[a]	4.80[b]	0.06
10	8.13[a]	7.96[a]	7.46[b]	8.14[a]	8.07[a]	7.60[b]	0.11
12	12.63[a]	12.20[b]	11.83[bc]	12.48[ab]	12.26[ab]	11.61[c]	0.15
14	17.71[a]	17.37[a]	17.39[a]	17.70[a]	17.33[a]	16.34[b]	0.28
16	23.04[bc]	23.20[b]	23.43[b]	24.43[a]	23.33[b]	22.34[c]	0.30
18	27.64	27.80	28.03	28.75	28.05	27.34	0.35

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[3] Ages 8-18 are in weeks and weights are in kg.

[a, b, c] Means within a row with different superscripts are significantly different ($p<0.05$).

[α] Except the Lubing Traditional Nipple which was changed to the Plasson Turkey Bell at 6weeks, all nipple drinkers remained in use for the duration of the project. The Ziggity, Big-Z Activator was changed to the Plasson Turkey Bell at 14 weeks when the body weights of those birds became significantly below all other drinker types.

Table 13. Cumulative feed consumption (kg/bird) of Large White commercial turkey females from placement to six weeks of age reared on different feed treatments[1].

	DFM[1]	Control	SEM
Age[2]			
1	0.127[b]	0.139[a]	0.002
3	0.314[b]	0.341[a]	0.006
5	1.76	1.76	0.01
6	2.34	2.32	0.02

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Ages 1-6 are in weeks and body weights are measured in kg.
[a, b] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 14. Cumulative feed consumption (kg/bird) of Large White commercial turkey females from eight weeks of age to market reared on different feed treatments[1].

	DFM[1]	Control	SEM
Age[2]			
8	4.88	4.82	0.04
10	7.92	7.86	0.06
12	12.19	12.15	0.09
14	17.35	17.27	0.16
16	23.33	23.26	0.17
18	27.93	27.95	0.21

[1] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.
[2] Ages 8-18 are in weeks and body weights are measured in kg.

Table 15. Litter moisture (%) beneath the drinker of Large White commercial turkey females from placement to six weeks of age reared on different drinker types[1].

	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[2]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[3]							
1	16.03	19.52	8.08	24.38	25.00	8.55	6.61
2	22.14[a]	21.11[ab]	15.35[b]	17.14[ab]	13.32[b]	15.70[b]	1.97
3	35.71[a]	24.50[b]	25.68[b]	25.23[b]	21.84[b]	22.73[b]	2.18
4	60.92[a]	58.70[a]	41.92[b]	53.29[ab]	61.69[a]	40.24[b]	4.94
6	49.81[b]	65.63[a]	47.99[b]	54.60[ab]	50.41[b]	44.64[b]	4.03

[1] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).
[2] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.
[3] Ages 8-18 are in weeks and weights are in kg.
[a, b, c] Means within a row with different superscripts are significantly different ($p<0.05$).

Table 16. Litter cake[1] in pens of Large White commercial turkey females from nine weeks to market reared on different drinker types[2α].

	Plasson Bell	Plasson Easy Start	Lubing Traditional Nipple[3]	Lubing EasyLine™	ValCo Turkey Drinker	Ziggity, Big-Z Activator	SEM
Age[4]							
9	27.75	22.65	26.85	36.82	29.98	3.30	10.10
12	65.04[a]	64.32[a]	17.79[b]	63.98[a]	40.23[ab]	6.93[b]	13.66
18	41.88	78.18	50.85	35.41	36.81	31.54	10.81
Total[5]	153.98[a]	176.51[a]	103.21[b]	145.85[ab]	141.50[ab]	41.75[c]	17.83

[1] Litter cake was removed from pens and weighed in kg

[2] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[3] Lubing Traditional Nipple is the FeatherSoft® high flow nipple with Littergard®.

[4] Ages 9-18 are in weeks and weights are in kg.

[5] Total litter cake is the sum of all cake removed throughout the course of the trial.

[a, b, c] Means within a row with different superscripts are significantly different ($p<0.05$).

[α] Except the Lubing Traditional Nipple which was changed to the Plasson Turkey Bell at 6weeks, all nipple drinkers remained in use for the duration of the project. The Ziggity, Big-Z Activator was changed to the Plasson Turkey Bell at 14 weeks when the body weights of those birds became significantly below all other drinker types.

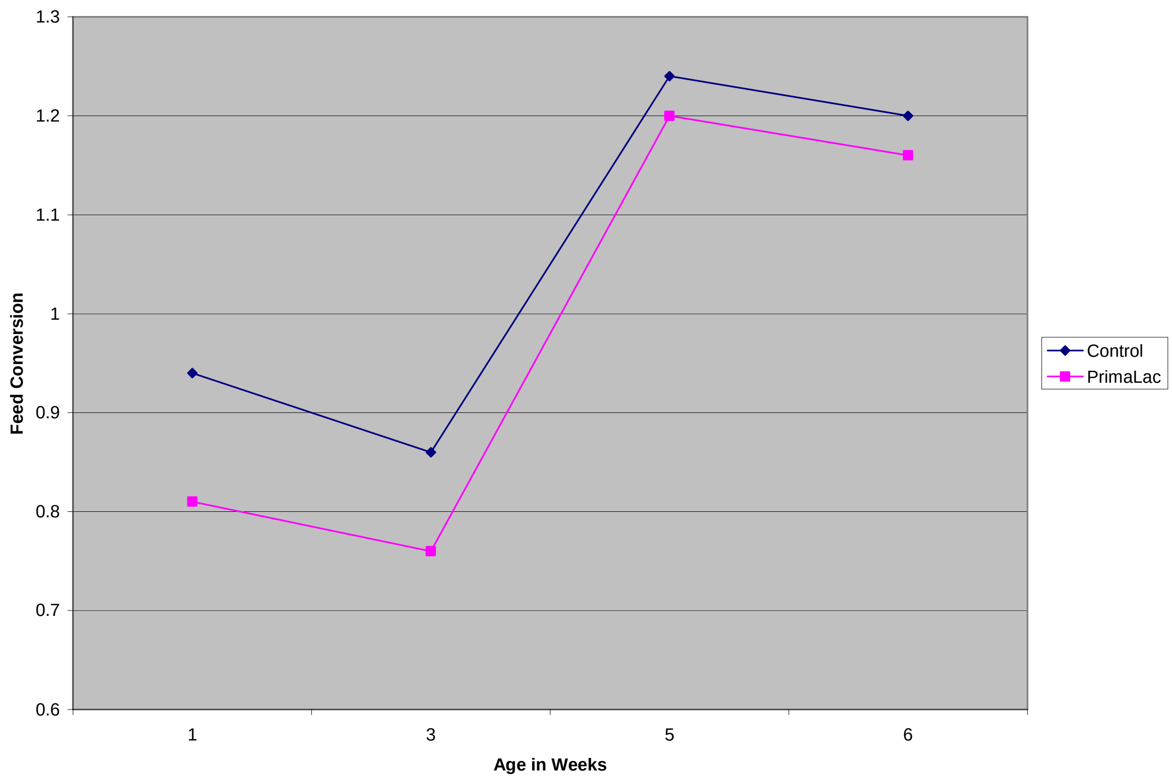

Figure 1. Cumulative feed conversion[1] of Large White commercial turkey females from placement to six weeks of age reared on the direct-fed microbial[2].

[1] Cumulative Feed Conversion was significantly different at all data points (SEM= 0.01).
[2] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.

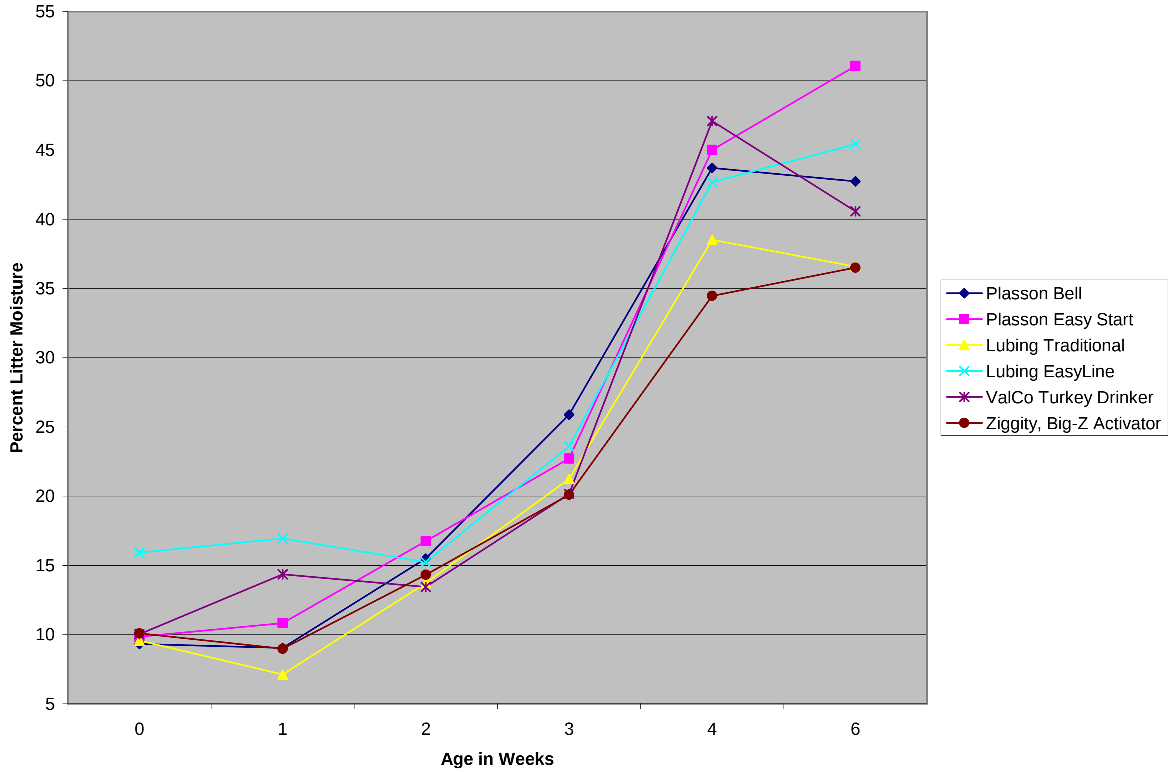

Figure 2. Litter moisture[1] (%) in pens of Large White commercial turkey females from placement to six weeks of age reared on different drinker types[2].

[1] Litter Moisture (%) was taken as a composite sample of the whole pen, and there were not significant differences at any data point (SEM=2.12%).

[2] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

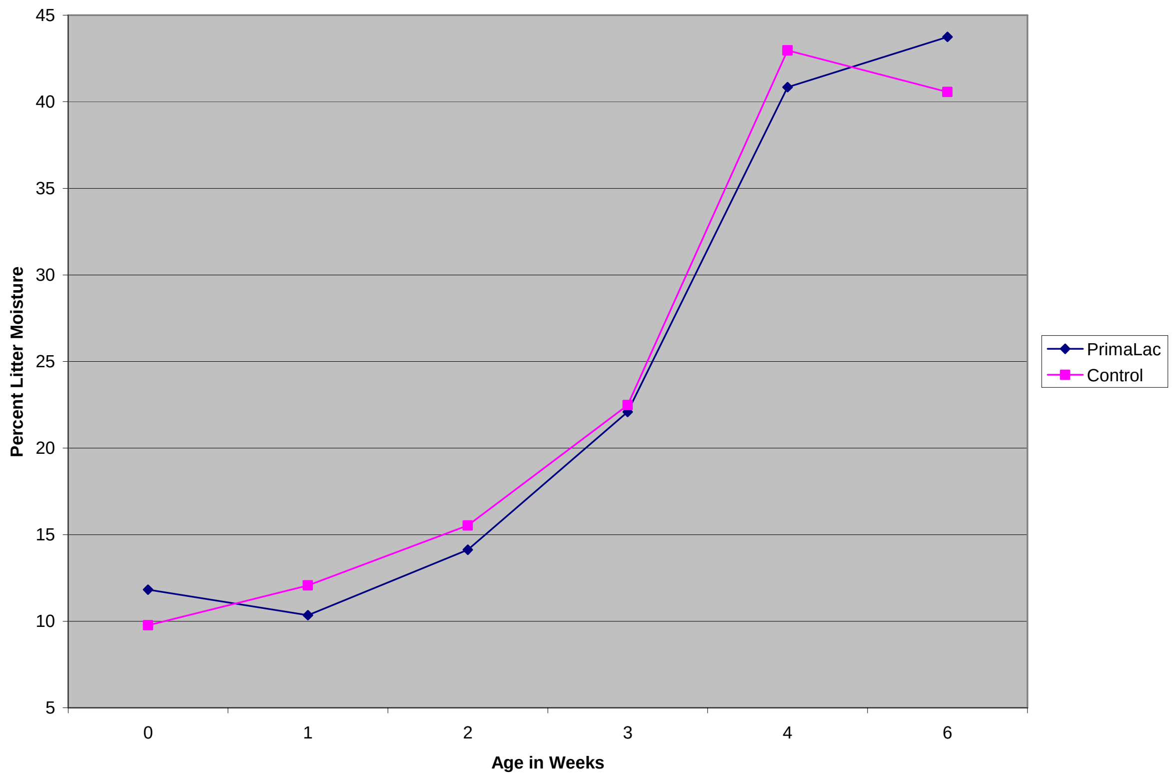

Figure 3. Litter moisture[1] (%) in pens of Large White commercial turkey females from placement to six weeks of age reared on different feed treatments[2].

[1] Litter Moisture (%) was taken as a composite sample of the whole pen, and there were not significant differences at any data point (SEM=1.28%).

[2] PrimaLac® (Star Labs, Clarksdale, MO).

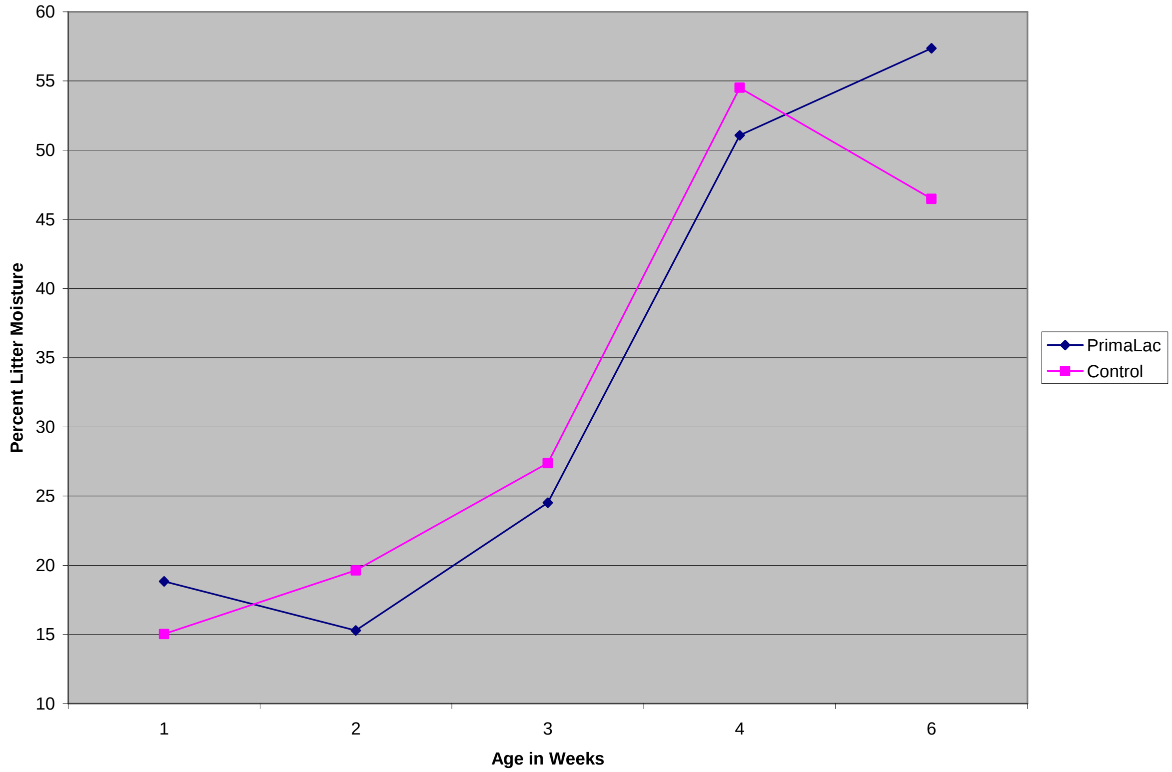

Figure 4. Litter moisture[1] (%) beneath the drinker of Large White commercial turkey females from placement to six weeks of age reared on different feed treatments[2].

[1] Litter Moisture (%) was taken as a composite sample beneath the drinker, and there were not significant differences at any data point (SEM=1.96%).
[2] PrimaLac® (Star Labs, Clarksdale, MO).

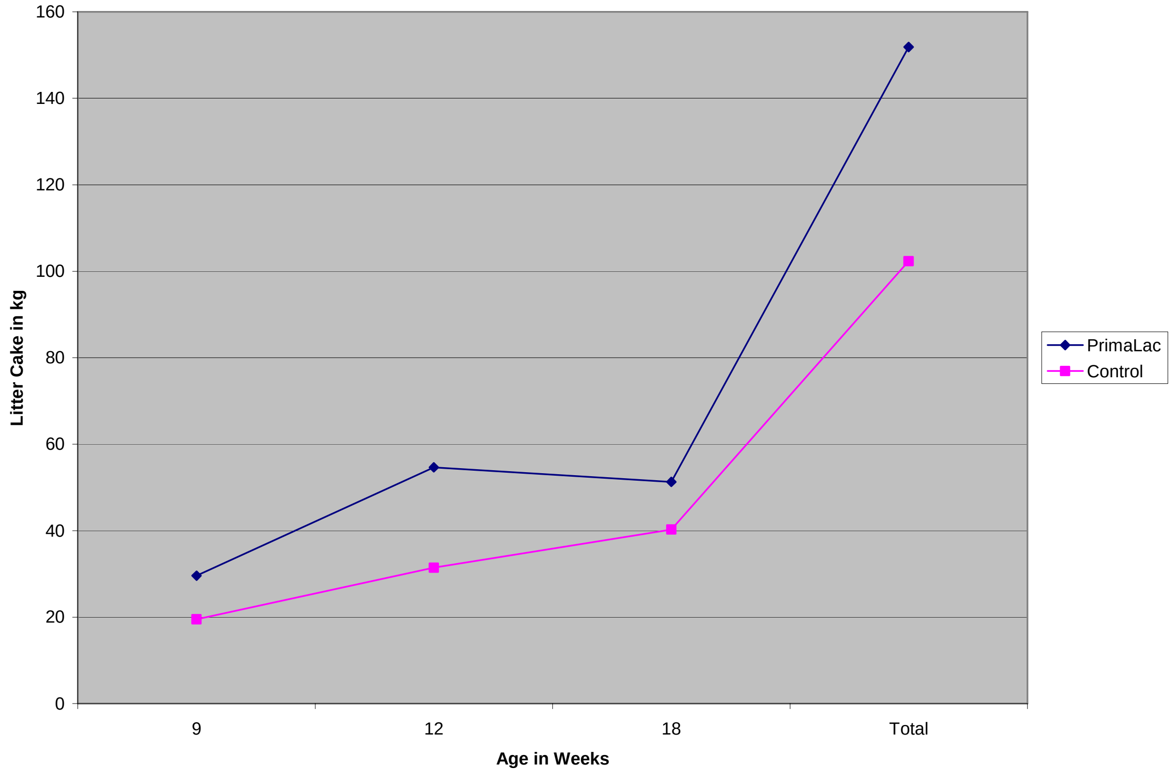

Figure 5. Litter cake[1] in pens of Large White commercial turkey females from nine weeks to market reared on different feed treatments[2].

[1] Litter cake was removed from pens and weighed in kg, and total litter cake is the sum of all cake removed throughout the course of the trial. Litter Cake was significantly different at 12 weeks. Total litter cake was significantly different by feed treatment (SEM=16.96kg).

[2] PrimaLac® (Star Labs, Clarksdale, MO).

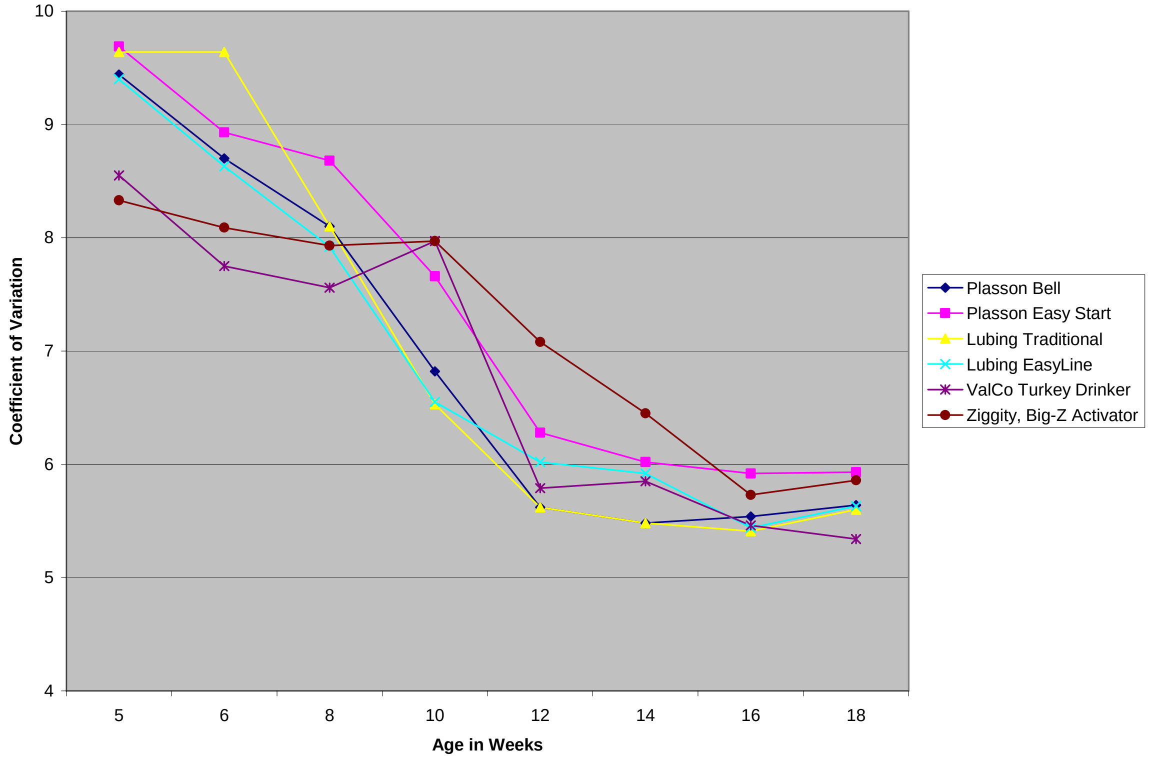

Figure 6. Coefficient of variation[1] of the body weight of Large White commercial turkey females reared on different drinker types[2α] from five weeks of age to market.

[1] There are no significant differences at any data point (SEM=0.47).

[2] Drinker Types: Plasson Bell and Plasson Easy Start (Diversified Imports, Maagan Micheal DN Mensashe, Israel, 37805), Lubing Traditional Nipple and Lubing EasyLine™ (Lubing, Cleveland, TN 37311), Ziggity, Big-Z Activator (Ziggity, Watering Systems, Inc., Middlebury, Indiana, 46540), and ValCo Turkey Drinker (Val-Co, Lancaster, Pennsylvania, 17603).

[α] Except the Lubing Traditional Nipple which was changed to the Plasson Turkey Bell at 6weeks, all nipple drinkers remained in use for the duration of the project. The Ziggity, Big-Z Activator was changed to the Plasson Turkey Bell at 14 weeks when the body weights of those birds became significantly below all other drinker types.

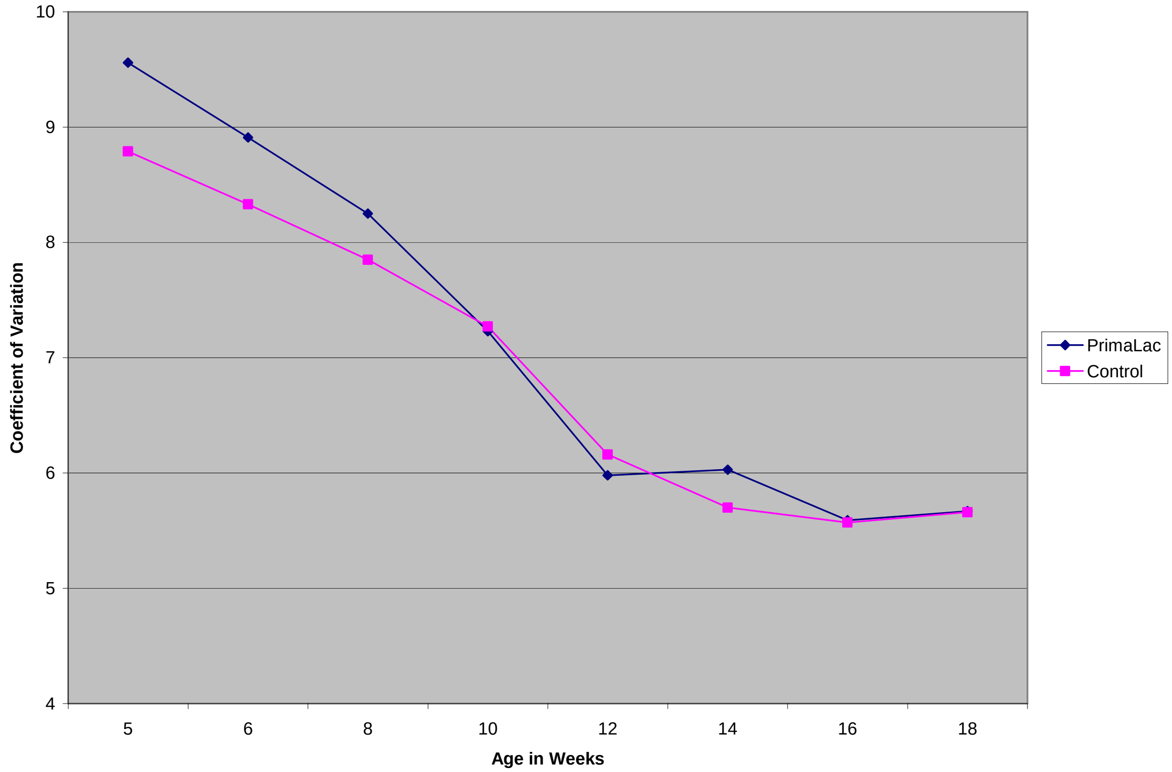

Figure 7. Coefficient of variation[1] of the body weight of Large White commercial turkey females reared on different feed treatments[2] from five weeks of age to market.

[1] There are no significant differences at any data point (SEM=0.27).
[2] PrimaLac® (Star Labs, Clarksdale, MO) is the direct-fed microbial (DFM) used.

SUMMARY

Three experiments were conducted with Large White Commercial Turkeys reared on six drinker types and two diets formulated with and without a direct-fed microbial. Performance parameters were used to measure the efficacy of these treatments. In trial 1, 6 week body weights of birds reared on the Plasson Easy Start and the Ziggity, Big-Z Activator were less than the body weights of those birds reared on the Plasson Bell. Differences in body weight due to drinker type remained through 10 weeks. At 20 weeks, body weights of birds on the Lubing Traditional Nipple and the ValCo Turkey drinker were significantly lower compared to body weights of birds on all other drinkers. There were no differences in feed conversion by drinker type until 20 weeks of age. Feed conversion was significantly improved for birds fed the direct-fed microbial throughout the trial, and body weight was significantly greater for birds fed the direct-fed microbial through 12 weeks of age.

Trial 2 – experiment 1 was terminated at 3 weeks because of excessive mortality by strain and drinker type. In trail 2 – experiment 2, body weight of birds reared on the Plasson Bell and the ValCo Turkey drinker was higher compared to body weights of birds reared the Plasson Easy Start and the Ziggity, Big-Z Activator with the body weights yielded by the Lubing EasyLine™ being intermediate at 6 weeks. The Lubing Traditional Nipple yielded significantly lower body weight compared with all other drinkers through 10 weeks of age. By 16 weeks, there were no longer differences in body weight due to drinker type. Drinker type did not have a significant effect on feed conversion. Body weight was significantly increased and feed conversion was significantly improved for birds fed the direct-fed microbial.

CONCLUSION

True nipple drinkers generally yielded decreased body weight, but their affect depends greatly on bird age and drinker design. Nipple drinkers modified for use in turkeys to provide an open water reservoir resulted in better turkey performance than true nipple drinkers. Nipple drinkers can have some effect on feed conversion. The birds that experienced decreased body weight as a result of being reared on nipple drinkers also had improved feed conversion. Additionally, litter moisture and overall litter condition was improved when nipple drinkers were used. This improvement may be furthered in the field with implements in place to alter bird's negative interaction with the drinkers preventing excess water spillage and damage to the drinkers themselves. Overall, nipple drinkers systems are effective through the brooding period for turkeys with some systems being capable of carrying birds through to market age and weight.

It was originally speculated that the direct-fed microbial used would be most beneficial to those birds whose growth was restricted as a result of being reared on nipple drinkers, but this was not observed in these studies. The effect of the direct-fed microbial was seen equally across all treatments. Body weight was significantly increased for birds fed the direct-fed microbial though 12 weeks of age. Feed conversion is generally improved for birds fed a direct fed microbial. This affect was seen throughout trial 1, and through 8 weeks in trial 2 – experiment 2. Further research with direct-fed microbials is warranted to ascertain how these products elicit their effect, which microbes elicit the greatest response under commercial conditions, and to further evaluate their effects on performance. The direct-fed microbial used herein is a viable alternative candidate to dietary antibiotics for rearing turkeys. Further research, comparing a direct-fed microbial to an antibiotic growth promoter, is needed to ascertain the true viability of direct-fed microbial products.