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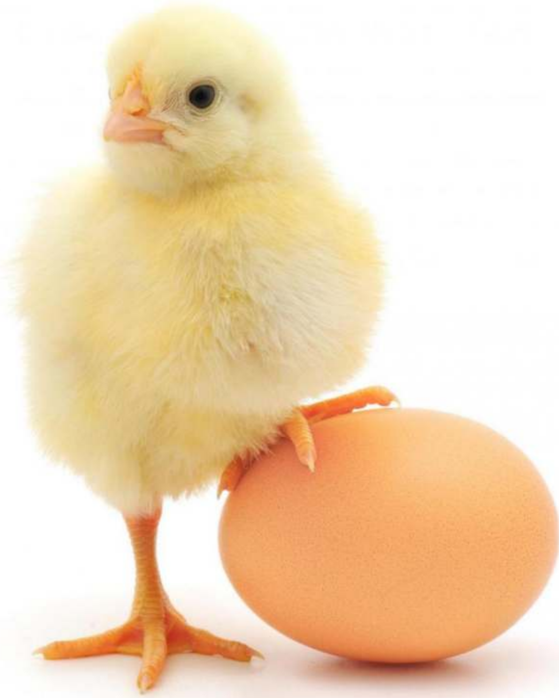

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Selenium Yeast Effect on Broiler Performance[1]

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Abstract: Positive responses attributed to selenomethionine in Se-yeast (Sel-Plex™ [SP], Alltech, Inc., Nicholasville, KY 40356)-supplemented feed have increased the interest in use of SP in all phases of poultry production. Experiments to test the influence of SP on performance parameters in broiler males (Arbor Acres X Arbor Acres) in floor pens were conducted. A completely randomized experimental design incorporated four Se-supplementation treatment groups [(1) No Se, (2) sodium selenite (NaSe; 0.2 ppm), (3) SP (0.2 ppm), and (4) NaSe (0.1 ppm)+SP (0.1 ppm)]. Body weights (BW), feed conversions (FCR), cut-up carcass yield, breast meat drip loss and serum thyroid hormones were measured through 6 wk of age. BW of SP-fed broilers were increased compared to No Se or NaSe treatment groups and the combination of NaSe and SP was no more effective than SP alone. FCR improved with Se supplementation with the SP and SP+NaSe being superior to NaSe only treatment. Feather yield was increased by SP treatment compared to all other treatments. Carcass weight, yields of viscera, feet, leg and thigh and neck were higher in SP-treated birds Increased breast meat drip loss was induced by NaSe. The serum thyroxin (T_4) levels were higher in birds within No Se treatment as compared to NaSe or SP. The ratios between serum T_4 and tri-iodothyronine (T_3) indicate that SP treatment facilitated the conversion of T_4 to T_3. The results suggest that Se from SP was used more efficiently for performance in fast growing, high yielding broiler chickens.

Key words: Selenium, broiler, performance, yield, thyroid hormones

Introduction

In, 1818, the Swedish chemist, Berzelius, discovered selenium (Se) and determined that it was an element closely associated with sulfur and tellurium. Unfortunately, the biological significance of this element was not recognized until it was identified as the toxic agent linked with “alkali disease” or selenosis, in the Dakota and Wyoming territories in the United States (Franke, 1934). Until, 1957, Se was considered to be a dangerous element, but Schwarz and Foltz (1957) found Se to be an essential dietary nutrient that prevented nutritional liver necrosis in rats. In the same year, prevention of exudative diathesis by Se was reported in chicks (Patterson *et al.,* 1957). Nutritionists soon initiated extensive studies to discover the metabolic function (s) of Se and document the consequences of its deficiency in human and animal diets. Se deficiency manifests itself in poultry in many diseases and dysfunctions including liver necrosis, muscular dystrophy, microangiopathy, exudative diathesis, pancreatic fibrosis, poor feathering, immune deficiency, reduced hatchability and many others (Edens, 1996).

The signs of Se deficiency in chickens have been related to the role of Se in antioxidant protection via the enzyme glutathione peroxidase (GSH-px). For many years, this was the only known role of Se in any species. More recently, a number of selenoproteins have been identified that both expand our knowledge of the physiological function of Se and aid in explaining other signs of Se deficiency (Arthur, 1997; Jacques, 2001; Edens and Gowdy, 2005).

Due to the similarities between Se and sulfur, it has been a long held belief that Se would follow sulfur pathways in its metabolism. Burnell and Whatley (1977) strengthened this concept when they reported that plants and bacteria metabolize Se to the organic selenomethionine and selenocysteine. Selenomethionine is readily utilized as a substrate by enzymes that use methionine and selenomethionine may even be more available than pure methionine (Markham *et al.,* 1980).

It has been accepted for many years that the selenoamino acids: selenomethionine, selenocysteine, and selenocystine, are the primary sources of naturally occurring Se in plant-based (Burk, 1976) and meat-based (Levander, 1986; Cai *et al.,* 1995) feed ingredients. The selenoamino acids are bound in protein, predominantly as selenomethionine and selenocysteine and can constitute up to 80% of the total Se in plants, grains (Butler and Peterson, 1967) and in Sel-Plex™, the organic Se-yeast (Kelly and Power, 1995). In June, 2000, the United States FDA approved selenium yeast (Sel-Plex™, SP) as an organic Se source for the use in broiler chickens. Conventionally, Se has been supplemented in animal feeds in the inorganic form as sodium selenite (NaSe). SP affords a mixture of organic Se compounds (Kelly and Power, 1995), but the primary form is selenomethionine in the yeast cellular protein component. The organic Se in SP is readily available and is actively absorbed from the intestine via the Na^+-dependent neutral amino acid pathway while selenite is passively absorbed (Schrauzer, 2000). Furthermore, it has been reported that SP is superior to NaSe in conditions of induction of feathering, causing sex-linked slow feathering broiler males and normal feathering females to increase feather development (Edens *et al.*, 2000), in tissue accumulation and retention in broilers (Norheim and Moksnes, 1985) and in reducing drip loss from breast meat (Edens, 1996; Downs *et al.*, 2000; Naylor *et al.*, 2000). The above-mentioned positive responses to SP supplementation have fueled interest in the use of SP in all sectors of the poultry industry. Therefore, it is crucial to not only continue the comparison of the influence of Se sources on production performance of high yielding broilers but to also elucidate the influence of organic Se on physiological and biochemical stability of the broiler chicken.

The objectives of these studies were:

1) To determine the influence of Se source on production performance of broilers,
2) Determine the influence of Se source on cut-up yields from carcasses of broilers,
3) Determine the influence of Se source on drip loss from breast meat of broilers and
4) Determine the influence of Se source of serum thyroid hormone levels in broilers.

Materials and Methods

Animal welfare: This project was approved and conducted under the supervision of the North Carolina State University Animal Care and Use Committee, which has adopted Animal Care and Use Guidelines governing all animal use in experimental procedures.

Animals and experimental treatments: A series of experiments was conducted to determine the influence of SP on production performance of high yielding Arbor Acres x Arbor Acres cockerels. The studies were conducted in conventional broiler production facilities. In the experiments, 40 birds were placed in each of 32 floor pens measuring 1.09 x 3.72 m. The pens contained two feeders and one Plasson drinker and fresh pine wood shavings litter.

Diets: The experimental diets consisted of a North Carolina Agricultural Research Service starter, grower, and finisher diet. The starter diet was fed from 1-16 days of age and consisted of 3177 kcal/kg ME and 22.5% CP. The grower diet was fed from 16-35 days of age and was 3168 kcal/kg and 19.5%CP. The finisher diet was formulated to contain an energy value of 3160 kcal/kg and 17.5% CP and was fed from 35-42 days of age (Table 1). The diets were supplemented with organic Se-yeast (SP, Sel-Plex^{TM} [SP], Alltech, Inc.) or NaSe at 0.2 mg Se/kg of feed. The background levels of Se were analyzed to be 0.28 mg/kg, 0.28 mg/kg and 0.24 mg/kg in the starter, grower and finisher diets, respectively. The feed was adjusted to allow per bird consumption an average of 2 lbs. of starter, 5 lbs. of grower and 2 lbs. of finisher. The experiment utilized a 2 x 2 factorially arranged completely randomized statistical design. Se was supplemented to the diets as follows:

Diet 1: No Se;
Diet 2: NaSe at 0.2 ppm Se;
Diet 3: SP at 0.2 ppm Se;
Diet 4: NaSe (0.1 ppm Se)+SP (0.1 ppm Se).

Parameters: Body weights (BW) were obtained at 2, 4 and 6 weeks of age and feed conversion ratios (FCR) and mortality were calculated through 6 weeks of age. Forty birds per treatment were taken for cut-up parts yield as a percentage of carcass weight and 20 birds per treatment were used to calculate drip loss from breast meat at 6 weeks of age. The pectoralis major was dissected and chilled in ice water for 4 hours. The muscle was blotted dry and a one-inch cube was cut and weighed. The cube was suspended from a stainless steel hook attached to the weight-tared lid of a weight-tared jar. The jar/lid unit was closed and was weighed and recorded on a 24-hour basis. By gravimetric analysis, drip loss was determined by weight changes in the weight-tared jar without the lid. During the processing of carcasses, a determination concerning the Pale Soft Exudative (PSE) status of the breast meat was made. Pale, friable breast muscle was considered as an exhibition of the PSE condition. Frequency of PSE was determined among the treatments.

At 2, 4 and 6 weeks of age, venous blood samples were collected from 20 birds per treatment. Blood was drawn into syringes without anticoagulant and introduced into serum separation tubes (Beckton Dickinson, Co., Franklin Lakes, NJ 07417) and allowed to clot. The clotted blood was allowed to sit for 6 hours at room temperature. The samples were then centrifuged at 400 x G for 30 minutes. Serum was decanted and frozen at -40°C until analyzed for thyroid hormones. The serum thyroid hormones, thyroxin and tri-idothyronine, were determined with the non-radioactive Morningstar ELISA assay (Morningstar Diagnostics, Inc., Naperville, IL 60563).

Statistical analysis: Data from the experiment were subjected to statistical analysis using the General Linear Model procedures of the Statistical Analysis System (SAS, 1996). Differences among means was assessed by least significant difference (SAS, 1996) and statements of significance were based on $P \leq 0.05$.

Results

Performance: Performance was improved in broilers fed SP when compared to birds fed No Se or NaSe (Table 2). Body weight (BW) at 42 days was increased in SP-fed broilers as compared to those in the No Se or NaSe treatment groups. The combination of NaSe and SP did not improve body weight over the SP group. FCR was improved by all Se sources, with the SP and SP+NaSe treatments superior to NaSe only. BW improvements were apparent in the SP fed chickens as early as 2 weeks of age but were improved significantly at 4 and 6 weeks compared to NaSe and No Se groups. FCR was improved by both Se sources when compared to FCR for broilers in the No Se treatment group. Feather yield was increased significantly in the broilers fed 0.2 ppm SP compared to NaSe and no supplemental selenium groups. The combination 0.1 ppm SP and 0.1 ppm NaSe decreased feather yield making it intermediate to SP and NaSe but still significantly greater than feather yield from the no supplemental selenium group (Table 2).

Cut-up yields of high-yielding broiler cockerels: On a percentage of carcass weight, yields of viscera, feet and neck were higher in SP treated birds (Table 2). As a percentage of carcass weight, yield of legs and thighs were increased and pectoralis major decreased slightly in SP treated birds compared to birds from the no supplemental selenium group (Table 4).

Breast meat drip loss: There was an increase in breast meat drip loss when birds fed NaSe were compared to the SP and No Se treatments (Fig. 1).

Serum thyroid hormones: The serum thyroxin (T_4) levels were higher in birds within the No Se treatment when compared to those supplemented with NaSe or SP (Fig. 2). No differences in serum T_4 were found due to Se source from 2-6 weeks of age. Serum tri-idothyronine (T_3) levels were lower in broilers given No Se compared to broilers supplemented with either NaSe or SP (Fig. 3). Serum T_3 levels were marginally lower in NaSe treated birds than those broilers fed SP. The ratios between serum T_4 and T_3 are shown in (Fig. 4).

Pale, soft and exudative breast meat: The data in Figure 5 demonstrate that SP was more efficient than NaSe in reducing the frequency of PSE breast meat from chickens reared in the spring and summer. The lower level of SP (0.1 ppm Se) was equivalent to or better than the higher inclusion rate (0.3 ppm Se) of NaSe in reducing the frequency of PSE meat.

Discussion

The National Research Council (1994) reported that the Se requirement to support normal broiler chickens was 0.1 ppm. The background levels of Se in the basal diets averaged 0.26 ppm during the course of these studies. In this case, the background level should have met the Se requirements of the broiler chickens involved in these studies. However, the data propose that there may be an additional requirement for Se by the faster growing, higher yielding broilers that are commonly grown today and that Se supplemented in the organic form may be more beneficial than inorganic forms of Se. The data illustrated that NaSe-fed broilers lagged behind the SP birds until 6 weeks of age, apparently because they were

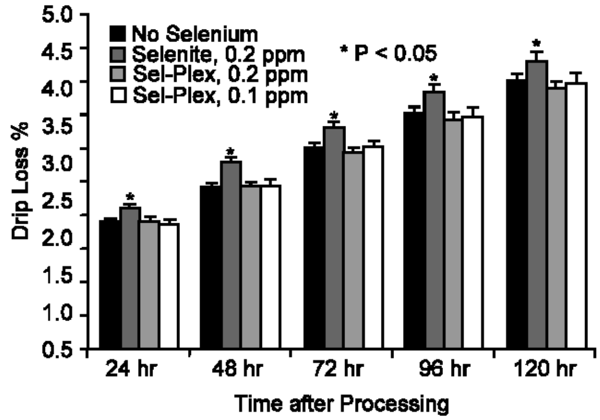

Fig. 1: Effect of selenium source (organic as Sel-Plex *vs.* inorganic as sodium selenite) on drip loss from male broiler breast meat. Vertical bars on the histograms represent standard error of the mean (SEM), and * above histogram bars indicates a significant difference ($P \leq 0.05$) compared with other means within a time period.

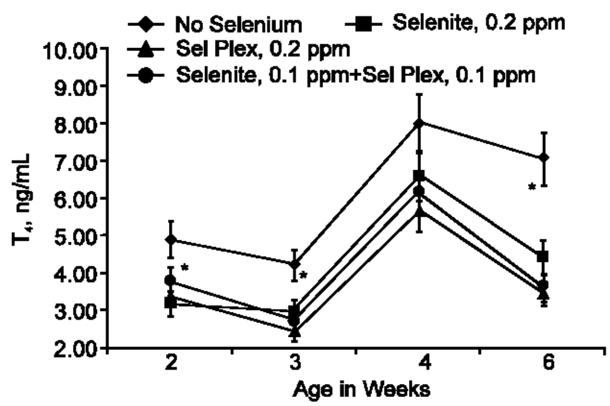

Fig. 2: Effect of selenium source (organic as Sel-Plex or inorganic as sodium selenite) on serum thyroxin (T_4) in broiler chickens. Vertical lines represent standard error of mean (SEM), and * indicates a significant difference ($P \leq 0.05$) between No Selenium and all other treatments.

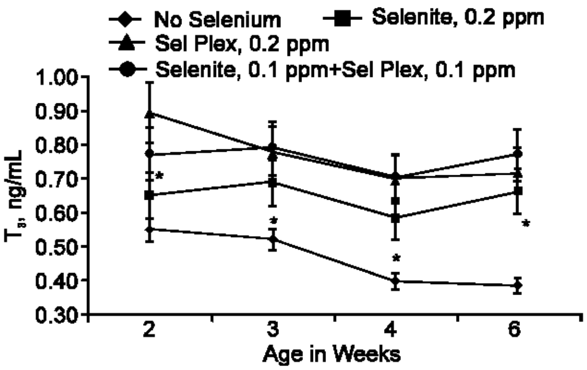

Fig. 3: Effect of selenium source (organic as Sel-Plex or inorganic as sodium selenite) on serum tri-iodothyronine (T_3) in broiler chickens. Vertical lines represent standard error of mean (SEM), and * indicates a significant difference ($P \leq 0.05$) between No Selenium and all other treatments.

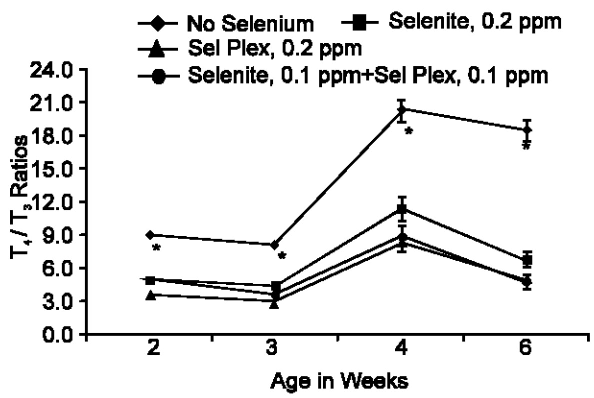

Fig. 4: Effect of selenium source (organic as Sel-Plex or inorganic as sodium selenite) on serum thyroxine (T_4) / tri-iodothyronine (T_3) in broiler chickens. Vertical lines represent standard error of mean (SEM), and * indicates a significant difference ($P \leq 0.05$) between No Selenium and all other treatments.

slower to feather during the first 5 weeks of age (Edens, 1996 and, 2001; Edens *et al.,* 2000). Granted, background levels of Se were sufficient to maintain good performance by the broilers in this study, but additional Se appeared to be necessary to optimize growth with birds given SP, either alone or in combination with NaSe, showing a greater response. Rutz *et al.* (2003) have reported that the use of NaSe in Ross broilers resulted in increased FCR, but replacement of NaSe by organic selenium as SP resulted in a 27 point improvement in FCR (2.29 in selenite-fed vs. 2.02 in SP-fed broilers).

The FCR data implied that an additional requirement for Se was necessary for the modern broiler chicken. The supplemental organic selenium in SP appeared to be superior to NaSe in satisfying the additional requirement. Improvements of 3-5 points in FCR represent highly significant feed cost savings for the producer. Part of that improved overall FCR can be attributed to improved rates of feathering on SP-fed birds (Edens, 1996 and 2001; Edens *et al.,* 2000), which meant that metabolic energy, which could be lost in NaSe-fed broilers, was actually retained and stored in the SP-fed broilers. These observations are consistent with those reported by Choct *et al.* (2004) who found a similar improvement in FCR of broilers fed organic selenium.

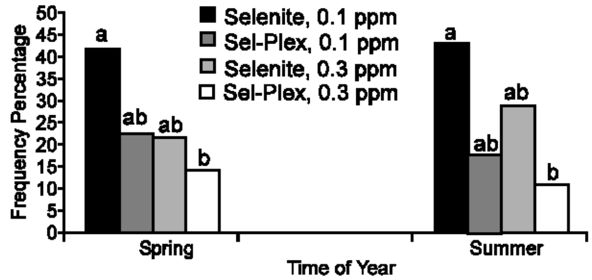

Fig. 5: Influence of selenium source (organic as Sel-Plex or inorganic as sodium selenite) on frequency of total pale, soft, exudative breast meat by treatment from male broiler chickens. Unlike lower case letters (a,b) above histogram bars indicates a significant difference among means ($P \leq 0.05$).

The drip loss data in this investigation suggest that NaSe Se may be associated with an oxidative process that promotes postmortem-development of compromised cell membranes and facilitates increased moisture loss from processed breast meat. It was not the supplementation of SP nor the absence of supplemental selenium that reduced the drip loss rate from breast meat, but it was the presence of NaSe that induced the highest drip loss rate in broiler breast meat (Fig. 1). These data are in agreement with Mahan's (1999) observations with swine (13.7% decrease in drip loss) and those of Downs *et al.* (2000) and Hess *et al.* (2003) in broiler chickens (47% decrease in drip loss 24 hours post-mortem). Naylor *et al.* (2000) also reported decreased drip loss rate (20-27% decrease in drip loss in SP-fed compared with NaSe-supplemented broilers). The data from this study show that there was 17% less drip loss over a 5 day period post-mortem observed from breast meat from broilers fed organic Se. This information is applicable to the poultry industry in many parts of the world because in poultry processing facilities, the processed carcass is chilled in a hypotonic ice-water bath. The flesh of the carcass usually absorbs the water from this ice bath due to the fact that the cytoplasmic compartment of the muscle cell is hypertonic to the ice water bath. Therefore, the muscle cells will absorb water, swell and many instances

Table 1: Composition of North Carolina Agricultural Research Service basal broiler diets.

	Ingredients as a Percentage of Diet Composition		
Ingredients	Starter	Grower	Finisher
Corn	59.08	68.61	76.62
Soy	26.95	19.30	15.38
Limestone	0.70	0.70	0.40
Dical Phosphate	0.70	0.80	
Poultry Fat	3.49	1.80	
Poultry Meal	7.98	8.00	6.79
DL-Methionine	0.18	0.04	
Lysine	0.07	0.09	0.05
Salt	0.40	0.20	0.30
Choline Chloride	0.20	0.20	0.20
Minerals1 (TM-90)	0.20	0.20	0.20
Vitamins2 (NCSU-90)	0.05	0.05	0.05
Selenium Premix	0.04	0.04	0.04
Total P, %	0.5882	0.5818	0.4068
Available P, %	0.3666	0.3751	0.2060
Meth+ Cys, %	0.93	0.72	0.626
S, %	0.7946	0.2945	0.2605
Ca, %	0.7946	0.8044	0.4649
Ca/Total P	1.3509	1.3826	1.1428
ME (Mcal/kg)	3.1773	3.1684	3.1601
DM, %	88.0500	87.5561	86.9629
CP, %	22.5051	19.5003	17.4814
EE, %	6.8655	5.4324	3.7168
Lino.Ac., %	2.3124	2.0864	1.7886
CF, %	2.6803	2.7278	2.8179

[1]Trace mineral (TM-90) premix provided in milligrams per kilogram of diet: Manganese, 120; zinc, 120; iron, 80; copper, 10; iodine, 2.5; cobalt, 1.0. Selenium premix as either sodium selenite or organic selenium (Sel Plex 50) was provided to each diet at a level to assure a concentration of either 0.1 or 0.3 ppm. [2]Vitamin premix (NCSU-90) provided per kilogram of diet: Vitamin A, 6,600 IU; cholecalciferol, 2,000 IU; Vitamin E, 33 IU (spring time study) or 16 IU (summer time study); Vitamin B12, 19.8 µg; riboflavin, 6.6 mg; niacin, 55 mg; pantothenic acid, 11 mg; Vitamin K, 2 mg; folic acid, 1.1 mg; thiamine, 2 mg; pyridoxine, 4 mg; biotin, 126 mg.

rupture if the amount of water absorbed exceeds the capacity of the cells. NaSe has been implicated in reactive oxygen metabolite (ROM) production (Edens and Gowdy, 2005). Cells that contain larger amounts of ROM experience compromised cellular membrane integrity. Therefore animals fed NaSe have a high probability of increased drip loss by reason of ROM production. The use of SP as a source of supplemental dietary Se provides a more efficiently utilized form of organic selenium and facilitates a greater antioxidant enzyme presence in glutathione peroxidase (Edens and Gowdy, 2005), which then acts to more readily reduce peroxides and other free radicals that compromise cell membranes.

Pale, soft, exudative (PSE) meat is a problem of increasing proportions among high yielding meat animals. It has been studied extensively in swine and turkeys (Ferket and Foegeding, 1994). The afore-mentioned authors reported that high levels of vitamin E supplementation in the diet could control a great amount of the PSE problem in turkeys, which suggests that there may be an oxidative problem associated with post-mortem development of PSE poultry meat (Ferket and Foegeding, 1994). In research reported with broiler chickens, Van Laack *et al.* (2000) observed PSE developing when there was accelerated post-mortem glycolysis and rapidly decreasing pH in meat that was still warm. These conditions yield meat that is pale with decreased water holding capacity and poor texture (Ferket and Foegeding, 1994).

Our data suggested that a post-mortem oxidative stress might contribute to the development of PSE poultry meat. The NaSe-fed broilers were found to be more susceptible to PSE development than SP-fed broilers. These observations imply that superior tissue retention (more than a 2-fold increased retention reported by Downs *et al.,* 2000) of organic Se in SP and steady state release of organic Se for incorporation into the glutathione/glutathione peroxidase antioxidant system was important in the reduction of PSE condition in broiler chicken meat. The SP-supplied Se was significantly more effective in reducing the incidence of PSE than NaSe (Fig. 5). There are many factors, such as genetics, nutrition, stress, environmental temperature, pre-slaughter handling, meat pH and post-mortem cooling rate, that contribute to the development of PSE (Ferket and Foegeding, 1994; Lee and Choi, 1999). It is important to recognize the fact that increased frequency of PSE and increased drip losses are linked as meat quality issues, but they are also linked with lowered processing yields, increased cook losses and decreased juiciness of the meat (Lee and Choi, 1999). All of these meat quality factors manifested through PSE are associated in parallel with oxidative tissue damage leading to drip loss.

In this study, cut-up yields of carcasses were influenced by Se source. A significant increase ($P < 0.05$) in the yields of the viscera, feet and neck as a percentage of carcass weight were found in SP fed animals. A large viscera weight might imply that feed passage could be slower and feed retention in the gut could be longer. The result of this condition could render more efficient utilization of feed. This result was observed in other studies (Naylor *et al.,* 2000; Roch *et al.,* 2000) where improved FCR was reported. The increase in yields of feet and neck and a trend toward a larger head appears to reflect improved growth in the SP-treated broilers. Feeding SP increased leg and thigh yields ($P < 0.05$), confirming earlier observations (Edens, 1996; Naylor *et al.,* 2000; Choct *et al.,* 2004), but in this single investigation, yield of pectoralis major muscle in the breast of male broilers fed diets supplemented with SP was slightly lower than the pectoralis major yield from birds given no supplemental selenium. It has been hypothesized that the cysteine/selenocysteine for earlier

Table 2: Influence of selenium source (inorganic as sodium selenite [NaSe] vs. organic as Sel-Plex) on mean (± SEM) body weight, feed conversion, mortality and feather weight

Treatment	Body Weight kg	Feed Conversion Feed/Body Wt. kg/kg	Mortality %	Feather Weight % Live BW
No Selenium	2.38^{b}	1.93^{a}	2.3^{a}	6.24^{c}
0.2 ppm NaSe	2.43^{ab}	1.87^{b}	2.5^{a}	6.55^{b}
0.2 ppm Sel-Plex	2.45^{a}	1.84^{bc}	2.3^{a}	6.95^{a}
0.1 ppm NaSe +0.1 ppm Sel-Plex	2.45^{a}	1.82^{c}	2.3^{a}	6.62^{ab}
SEM	0.009	0.005	0.01	0.005

a,b,c In a column, means with unlike superscripts differ significantly ($P \leq 0.05$).

Table 3: Influence of selenium source (inorganic as sodium selenite [NaSe] *vs*. organic as Sel-Plex) on mean (± SEM) percentage yield of parts based on carcass weight

Selenium Source	Viscera %	Feet %	Head %	Neck %	Fat Pad %	Rib %
No Selenium	13.84^{ab}	5.13^{b}	2.96^{a}	5.04^{ab}	1.47^{a}	6.35^{a}
NaSe 0.2 ppm	13.91^{ab}	5.33^{ab}	2.96^{a}	4.84^{b}	1.47^{a}	6.58^{a}
Sel-Plex 0.2 ppm	14.78^{a}	5.42^{a}	3.01^{a}	5.26^{a}	1.50^{a}	6.57^{a}
Sel-Plex 0.1 ppm + NaSe, 0.1 ppm	13.29^{b}	5.38^{ab}	3.07^{a}	4.96^{ab}	1.46^{a}	6.69^{a}
SEM	0.35	0.10	0.06	0.11	0.02	0.17

a,bIn a column, means with unlike superscripts differ significantly ($P \leq 0.05$).

Table 4: Influence of selenium source (inorganic as sodium selenite [NaSe] *vs*. organic as Sel-Plex) on mean (± SEM) percentage yield of parts based on carcass weight

Selenium Source	Drum %	Thigh %	Wing %	Pectoralis Major %	Pectoralis Minor %	Breast Skin %	Back %
No Selenium	12.18^{b}	15.06^{a}	9.56^{a}	16.69^{a}	4.28^{a}	2.43^{a}	18.25^{a}
NaSe 0.2 ppm	12.58^{ab}	15.29^{a}	9.73^{a}	16.37^{ab}	4.15^{a}	2.39^{a}	17.57^{a}
Sel-Plex 0.2 ppm	12.86^{a}	15.49^{a}	9.87^{a}	15.90^{b}	4.14^{a}	2.48^{a}	18.02^{a}
Sel-Plex 0.1 ppm + NaSe 0.1 ppm	12.58^{ab}	15.44^{a}	9.70^{a}	16.12^{ab}	4.21^{a}	2.37^{a}	17.76^{a}
SEM	0.18	0.24	0.19	0.22	0.07	0.10	0.27

a,bIn a column, means with unlike superscripts differ significantly ($P < 0.05$).

feathering might be diverted from the breast muscle causing the slight delay in development of the pectoralis major muscle (Edens, 1996). This might suggest that an even higher rate of SP supplementation (0.3 ppm or higher) would be even better than the 0.2 ppm used in this study. Naylor *et al*. (2000) and Choct *et al*. (2004) have reported increased SP-related yields of legs and thighs and feathers with no loss of breast meat yield in studies supplying up to 0.25 ppm as SP.

The serum T_3 data suggest that supplemental Se is necessary for the increased conversion of serum T_4 to T_3. This observation further suggests that the background level of Se in the basal diet was not sufficient to effectively meet the requirements of the high yielding broiler line utilized in this study. The ratios between serum T_4 and T_3 indicated that as early as two weeks of age, the T_4/T_3 ratio between the thyroid hormones were elevated significantly in those broilers given diets without supplemental Se as compared to those broilers given NaSe or SP. Additionally, the ratios between the hormones strongly suggest that organic Se supplementation facilitated the conversion of T_4 to T_3. This observation suggested that the extra-thyroidal conversion of T_4 to T_3 was mediated by the hepatic Se-dependent type I, 5'-iodothyronine deiodinase enzyme (Edens, 2001).

The thyroid hormone data suggest that conversion of T_4 to T_3 was more efficient when SP was the supplemented Se source. Because thyroid hormones are implicated in feathering, the slightly higher levels of T_3 in SP fed birds could be linked to the improved feathering rate seen in birds in this investigation when they were fed SP (Table 2) and in earlier studies with broilers given supplemental SP (Edens, 1996; Edens *et al.,* 2000, Naylor *et al.,* 2000; Choct *et al.,* 2004). Furthermore, T_3 has been implicated in improved growth rates of animals (Jianhua *et al.,* 2000) and an increased rate of conversion of T_4 to T_3 suggests improved growth rate and efficiency potential as demonstrated in SP-fed broilers in this study.

Conclusion: The beneficial effects of SP on performance and improved physiological responses in broiler chicks support the conclusion that selenomethionine in Sel-Plex™ may be an essential form of Se supplementation for today's poultry. Improved performance as indicated by improved BW, FCR and improved yield and quality of processed broiler meats suggests that SP supplementation is superior to NaSe. The improved performance appears to be related to improved antioxidant status associated with the supplementation of organic selenium in the SP.

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