The effect of vitamin premix in extruded plant-based and fish meal based diets on growth efficiency and health of rainbow trout, *Oncorhynchus mykiss* ★☆

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**ABSTRACT**

Trout diet formulations have changed considerably in the last ten years and modern diets reflect changing ingredient markets, feed processing technologies, and faster growing strains of trout. In contrast, most of the vitamin requirements for rainbow trout were determined more than 30 years ago and whether these requirements are appropriate for modern diet formulations is unclear. For these reasons, a study was conducted to determine the effect of protein source and vitamin levels in extruded feeds on growth performance and nutrient retention. A 2 × 4 factorial treatment design was used with two protein sources, fish meal and plant meals, and four vitamin premixes. All vitamin premixes contained the same vitamins but at different levels and included: 1) 100% of NRC [National Research Council (NRC), 1993. Nutrient Requirements of Fish, National Academy Press, Washington, DC. 114 pp.] recommended vitamin level (NRC), 2) NRC levels with each vitamin independently increased for potential extrusion losses (variable retention, VR), 3) NRC levels with all vitamins increased to assume equal retention of 40% after extrusion (ER), and 4) negative control with no vitamin premix added (None). Each of the 8 diets was fed to groups of 35 rainbow trout (4.8 g) in 150-L fiberglass tanks (5 replicate tanks per diet, except for the negative control diets with 3 replicates) for 15 weeks. Each tank was supplied with 6 L/min of untreated, constant temperature (14.5 °C), spring water. Signs of a pantothenic acid deficiency were observed within 6 weeks for the fish fed the plant-based diet without vitamin premix and signs of a vitamin E deficiency were observed for the trout fed the fish meal-based diet without vitamin premix. These treatments were terminated after 9 weeks. Among the supplemented diets, vitamin premix did significantly affect survival, feed intake, protein retention efficiency (PRE), energy retention efficiency, hematocrit and HSI, but not weight gain or FCR. Significant interactive effects between vitamin premix and protein source were observed for survival, hematocrit, HSI, and PRE. Vitamin retentions after extrusion were similar to reported values with the exception of vitamin A, folic acid, and thiamin. Results indicate that the vitamin levels recommended by NRC do not appear to be adequate for young, fast growing trout fed extruded feeds. Adjustment of individual vitamins in the premix to account for vitamin destruction during the extrusion process will maintain levels in the final feed at target levels while reducing vitamin costs associated with over-supplementation.

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1. Introduction

Numerous studies have been conducted on replacing all or a portion of fish meal in aquaculture diets with plant-based ingredients, and the results indicate with carnivorous fish species, such as Atlantic salmon and rainbow trout, that substantial portions of the fish meal can be removed without reducing growth (Arnesen et al., 1990; Krogdahl et al., 1994; Arndt et al., 1999; Refstie et al., 2000, 2001; Vielma et al., 2000).

Ingredients that can substitute for fish meal need to have wide availability, competitive price, ease of handling, shipping, and storage, and sustainability of production (Gatlin et al., 2007). Plant-derived products fit those criteria well, but can have vastly different nutrient and anti-nutrient profiles from fish meal. Recent feeding studies with concentrated plant protein and rainbow trout have indicated that these ingredients can replace all the dietary fish meal with either no reduction or just a slight reduction in growth (Kaushik et al., 1995; Yamamoto et al., 2002; Gaylord et al., 2006; Barrows et al., 2007). As the price of fish meal continues to increase, the composition of aquaculture feeds will change with decreased amounts of fish meal and increased amounts of alternative ingredients including plant-
derived products. Consequently, as the composition of the diet changes the contribution of endogenous vitamins will also change (Athar et al., 2006) because the contributions of specific vitamins vary among ingredients (Lebiedzinska and Szefer, 2006). Kaushik et al. (1998) demonstrated that recommended vitamin levels (NRC, 1993) were adequate for rainbow trout fed a practical fish meal/soybean meal diet, but inadequate in a casein/gelatin, semi-purified diet. In commercial aquaculture diets, the contributions of vitamins from ingredients are not normally considered. However, vitamins from ingredient sources could make a significant contribution to fish performance when feed is stored for too long, stored under poor conditions (Barrows and Hardy, 2001) or cooked (Leskova et al., 2006) with the latter being particularly relevant to modern aquafeed manufacture.

The primary processing method for aquafeeds has changed in approximately the last 15 years from compression pelleting to cooking extrusion (Barrows and Hardy, 2000). Cooking extrusion is an aggressive processing method that has been documented to cause significant destruction of vitamins in supplements (Anderson and Sunderland, 2002) and ingredients (Killiet, 1994; Athar et al., 2006) and has a variety of effects on feed quality (Bjork et al., 1984; Hakansson et al., 1987; Barrows and Hardy, 2000; Stone et al., 2005). Because susceptibility to destruction by heat and pressure vary among the specific vitamins, no one processing condition can be used to minimize losses of all vitamins (Anderson and Sunderland, 2002). Similarly, dryer conditions and types have also changed in recent years. There is an economic incentive to process feed as quickly as possible to increase production, however, this can sometimes lead to increased dryer temperatures which can reduce vitamin retention in extruded diets (Anderson and Sunderland, 2002).

The philosophy behind the determination of vitamin requirements for fish, unlike that for other livestock where the goal is to determine the absolute minimum requirement diets, has historically focused on prevention of deficiencies for a wide range of environments and species (Woodward, 1994). However, the price competitive nature of fish farming is now more like other livestock requiring an increased precision in diet formulation to minimize input costs while maintaining maximum performance. Aggressive feed processing methods, a shift to plant-based ingredients, and the ever present need to minimize production costs, thus necessitate re-examining the adequacy of vitamin premix levels. The present study was conducted to evaluate and coalesce recent information on vitamin stability during extrusion, and develop an open-formula vitamin premix for plant-based or fish meal-based diets produced by cooking extrusion.

2. Materials and methods

2.1. Experimental design

A 2 × 4 factorial treatment arrangement was used to determine the effect and interaction of vitamin level and protein source in the diet of rainbow trout. A series of fish meal-free, plant-based diets (PL) with soy protein concentrate, corn gluten meal, wheat gluten meal and soybean meal as the primary protein sources were formulated to contain 40% crude protein and 15% crude lipid (Table 1). A second series of diets containing fish meal (FM) were designed to represent practical trout feeds (Table 1). Each of these diets was produced with one of four vitamin premixes to result in eight experimental diets. Vitamin premixes were formulated to contain; 1) 100% of NRC (1993) recommendations (NRC), 2) the same profile but with each vitamin increased to account for vitamin-specific extrusion losses (variable retention, VR), 3) all vitamins increased to assume equal retention of 40% after extrusion (ER) and 4) negative control with no vitamins added (None). VR vitamin levels were based on reported losses by Gadient and Fenster (1994), Gabaudan and Hardy (2000a,b), Anderson and Sunderland (2002) and Marchetti et al. (1999). Diets containing either protein source were supplemented with the same levels of trace minerals, however, the plant-based diets were supplemented with a macro-mineral premix containing phosphorus, sodium, potassium and magnesium to approximate the levels of these minerals in the fish based diets.

2.2. Fish and culture

A domesticated strain of rainbow trout, Oncorhynchus mykiss (House Creek strain, College of Southern Idaho) was used. Each of the 8 diets was fed to groups of 35 rainbow trout (4.8 g) in 150-L fiberglass tanks (5 replicate tanks per diet, except for the negative control diets with 3 replicates) for 15 weeks. Each tank was supplied with 6 L/min of untreated, constant temperature (14.5 °C), spring water. A fixed photoperiod, controlled by timers and fluorescent lights, was followed (14 h light:10 h dark). Fish were fed three times per day, six days per week to apparent satiation which was achieved when the fish would no longer aggressively consume feed. There were no wasted pellets for any of the diets during the study, so feed intake values represent actual feed consumed. The experimental protocol was approved by the University of Idaho’s Animal Care and Use Committee.

2.3. Diet preparation

All ingredients were ground to a particle size of <200 μm using an air-swept pulverizer (Model 18H, Jacobsen, Minneapolis, MN). The diets were processed using a twin-screw cooking extruder (DNDL-44, Buhler AG, Uzwil, Switzerland) with an 18 sec exposure to 127 °C in the extruder barrel. Pellets were dried with a pulse bed drier (Buhler AG, Uzwil, Switzerland) with an 18 sec exposure to 127 °C in air-swept pulverizer (Model 18H, Jacobsen, Minneapolis, MN). Diets were fed within 4 months of manufacture.

2.4. Chemical analyses

Feed and fish samples were dried, and analyzed using AOAC (1995) methods for proximate composition, with the exception of crude
protein and crude lipid. Dried samples were finely ground by mortar and pestle and analyzed for crude protein (total nitrogen × 6.25) using a LECO nitrogen determinator (TruSpec N, LECO Corporation, St. Joseph, MI). Crude fat was analyzed using a soxhlet extraction apparatus (Soxtec System HT, Foss Tecator AB, Hoganas, Sweden) with methylene chloride as the extracting solvent, and ash by incineration at 550 °C in a muffle furnace. Energy content of the samples was determined using a Parr bomb calorimeter (Parr Instrument Co., Moline, IL).

Vitamin content of feeds were determined by Eurofins (Memphis TN) for vitamin B6, AOAC 961.15; alpha tocopherol acetate, AOAC 971.30; folic acid, J. AOAC, 73.5, 1990; niacin, 944.13; thiamin hydrochloride, AOAC 942.23; riboflavin, AOAC 952.20/45.2.02; pantothenic acid, AOAC 945.74.

2.5. Calculation of performance indices and apparent digestibility coefficients

Fish performance indices were calculated using the following formulae:

- Apparent feed conversion ratio (FCR) = feed intake (dry weight)/body weight gain (wet weight)
- Apparent protein retention efficiency (PRE) = (protein gain in fish (g)/protein intake in feed (g)) x 100
- Apparent energy retention efficiency (ERE) = (energy gain in fish (g)/energy intake in feed (g)) x 100
- Hepatosomatic Index (HSI) = (liver weight (g)/body weight (g)) x 10
- Feed intake (Fl) %bw/d
- Gain, g = final wt./f-initial wt./fish
- Vitamin retention, total = (Pellet conc./Mash conc.)*100
- Vitamin retention, added = ((Pellet conc. - conc. in unsupplemented diet after extrusion) /Added conc.)*100

2.6. Histopathology

Fish fed the diets without vitamin supplementation were sampled for histopathological evaluation at 9 weeks. Fish in all other treatments were sampled at the end of the trial (15 weeks). At sampling, five fish from each of the replicate tanks were euthanized and samples of gill, kidney, liver, pyloric ceca and distal intestine were preserved in Davidson’s solution for 48 h. Tissues were then transferred to 65% alcohol until processed by standard histological procedures (Sheehan and Hrapchek, 1983).

2.7. Statistical analyses

Fish performance, nutrient retention and carcass composition data were analyzed using the general linear models procedure of the Statistical Analysis System (SAS, 1988). Tank mean values were considered units of observation for statistical tests, and mean values were considered significantly different when P<0.05. Differences in treatments means were separated using the Tukey multiple range test. Any value expressed as a percentage was arcsine transformed prior to analysis (Sokal and Rohlf, 1981). Data were also analyzed as a 2×3 factorial treatment design to evaluate main effects rather than just treatment means.

3. Results

3.1. Growth performance and hematocrit

Large increases in body weight were observed during the 15 week study, and fish fed diets with supplemental vitamins had 1700 to 2100% increases in body weight over initial weight. As expected, trout fed diets without a vitamin premix exhibited poor performance relative to the trout fed the supplemented diets (Table 2). Fish fed the diets without supplemental vitamins (premix None) were terminated at 9 weeks due to slow growth, deficiency signs and increasing mortality. Trout fed FM-None had decreased growth after 6 weeks. The mortality observed for the trout fed FM-None was very low until week 7, and then became very severe. Decreased growth was observed for the fish fed PL–None after only 3 weeks of feeding. Mortality began in week 4 for the trout fed PL-None and was slow but steady for the remaining 6 weeks. Fish in these treatment groups were not included in the statistical analysis.

Among supplemented diets, there was an effect of diet on survival during the trial (Table 2), with an effect of protein source and vitamin premix, and an interaction of these effects (Table 2). The trout fed FM-NRC had lower survival (93.7%), compared to fish fed PL-NRC (98.8%). The mortality of the trout fed FM-NRC occurred during the last 3 weeks of the study and histological evaluation indicated a vitamin E deficiency. The trout fed the supplemented plant-based diets, regardless of vitamin premix, had survival equal to or better than 98% and did not exhibit vitamin deficiency signs.

Growth of trout fed the PL diets, however, was significantly less than fish fed the FM diets (Table 2). The trout fed the PL diets gained an average of 84.7 g/fish, compared to 92.1 k/fish for the trout fed the FM diets, or approximately 8% less gain. Feed conversion ratio was also affected by protein source, but not vitamin premix (Table 2). Higher FCR values were observed for trout fed the PL diets relative to trout fed the FM diets, 1.00 and 0.95, respectively. In conjunction with higher FCR values, higher feed consumption was observed for trout fed the PL diets. Trout fed the FM based diets consumed on average 2.99% bw/d, compared to 3.35% bw/d for the trout fed the PL diets. There was no effect of vitamin premix on feed intake.

Both protein source and vitamin premix had an affect on hematocrit values and HSI (Table 2). An interaction of the protein source and premix was also observed for hematocrit and HSI. Hematocrits of trout fed PL-NRC were significantly lower than those of fish fed PL-VR or PL-ER, but all values were in the normal range, 43.0 and 51.5 and 55.7%, respectively. The trout fed FM-NRC had abnormally low hematocrit values of 7.0, and the blood was very pale and straw colored. Trout fed FM-VR had hematocrit values of 31.5% which was intermediate to hematocrits of fish fed FM-100 and premix FM-ER (54.6%). There was no effect of premix type on HSI for trout fed the PL diets, but there was an effect on HSI for trout fed the FM diets. The trout fed FM-NRC had an HSI of 1.31%, compared to 1.19% and 1.03% for the trout fed FM-VR and FM-ER, respectively.

3.2. Nutrient retention

There was an effect of vitamin premix but no effect of protein source on PRE (Table 2). An interaction of protein source and vitamin premix on PRE was observed. Within the FM diet series, the trout fed FM-NRC had a reduced PRE (30.2%) relative to the trout fed FM-VR (38.8%) or FM-ER premix (35.2%) while PRE were not different among the trout fed the PL diets (Table 2).
There was no interaction observed for protein and vitamin premix on ERE (Table 2). Trout fed premix NRC had lower ERE (30.1%) than trout fed the VR (35.3%) or ER (35.2%) premixes (Table 2). ERE was significantly improved for fish fed either the FM or PL diets by changing from the NRC premix to the VR premix, and no further increases were observed when the ER premix was fed.

### 3.3. Body composition

There was a significant effect of diet on body crude protein, crude lipid, moisture and energy content, but not on ash content (Table 2). Protein source affected both the protein and crude lipid composition of trout. Trout fed PL diets had higher crude lipid (40.5%) and lower crude protein (53.5%) than the trout fed FM diets (37.6% crude lipid and 56.4% crude protein). There was no effect of vitamin premix on body crude protein content, but there was an effect of vitamin premix on body crude lipid content. Trout fed FM–ER had lower body crude lipid levels than trout fed any of the PL diets. Vitamin premix, but not protein source, affected the body moisture content (Table 2). The trout fed the diets with premix VR had 73.2% moisture, while the trout fed the diets with premix NRC and ER, respectively, had 74.9% and 74.5% moisture. The trout fed the PL diets had higher energy content (6640 kcal/kg) than trout fed the FM diets (6472 kcal/kg).

### 3.4. Histopathology

Severe histopathological changes were noted in tissue of trout fed FM–None and PL–None at 9 weeks post-feeding, and the changes observed were dependent on dietary protein source. Trout fed FM–None exhibited primarily signs associated with vitamin E deficiency with ceroid pigment common in livers of all fish resulting in diffuse swelling and necrosis of hepatocytes (Fig. 1). Ceroid was also found in large amounts in hematopoietic tissue of anterior and posterior kidney. Spleens of most fish exhibited signs typical of nutritional gill disease due to pantothenic acid deficiency. Both early and late stages of the disease were observed. Changes consisted of fusion of gill lamellae starting at the tips of filaments and progressing towards the bases of the filaments in the early stage. In the later stage, total fusion of lamellae and often several filaments had occurred (Fig. 2). Changes in liver tissue were variable with mild to moderate numbers of cells showing nuclear inclusions/vacuolation in hepatocytes of most fish. Mild to moderate pathological changes were noted in hematopoietic tissue of anterior and posterior kidney. Spleens of most fish contained mild to moderate amounts of ceroid/lipofuscin. All tissues of the gastrointestinal tract were normal as was heart and skeletal muscle.

![Fig. 1](image-url) Large amounts of ceroid pigment is present in liver tissue (arrows) indicative of a vitamin E deficiency in trout fed FM–None. Necrotic hepatocytes are scattered throughout tissue. Bar = 50 µm.
Only trace amounts of ceroid deposition was seen in liver cells of fish fed FM-ER and FM-VR and was mostly present in macrophages lining blood sinusoids. Ceroid deposition, however, was present in livers of all fish fed the FM-NRC diet and was moderate to severe. In addition, diffuse necrosis, nuclear pleomorphism and bile duct proliferation were seen in livers of several fish fed either the FM-NRC or PL-NRC (Fig. 3). Ceroid was present in spleens of most fish fed the FM diets. Ceroid was absent from livers and spleens of fish fed all PL diets, but was present in small amounts in spleens of fish fed FM-NRC.

Varying numbers of cells containing nuclear inclusions/vacuolation, (Fig. 4) and diffusely scattered cells with foamy cytoplasm were seen in livers of a few fish fed both the FM and PL diets, but was present to a lesser degree in livers of fish fed diets with the premix ER. Some of these cells were extremely swollen and undergoing degeneration. The cause of these changes is unknown, but is not consistent with reported specific vitamin deficiencies.

3.5. Analyzed vitamin composition

As expected, analysis of diets after extrusion demonstrated differences in vitamin content among the diets with different vitamin premixes (Table 3). Comparison of vitamin levels in PL-None and FM-None reveals the difference in vitamin contributions from ingredients. Higher levels of vitamin A were observed in the PL-None diet (2,820 mg/kg) relative to the FM-None diet (1,310 mg/kg). The riboflavin content of the PL-None diet (2.7 mg/kg) was slightly below the NRC requirement and the level of riboflavin in the FM-None (5.1 mg/kg) diet was just slightly above the requirement of 4.0 mg/kg. The levels of vitamins present in the diets supplemented with premix NRC and VR reflected the supplementation levels.

Vitamin retention values reflect the loss of vitamins in the feed due to processing and storage loss. Differences in vitamin retention values for vitamin A and pantothenic acid were observed between the PL and FM diets (Tables 4 and 5). Retention value for vitamin A in the PL diet was high, 59%, compared to only 11% in the FM diet. Similarly, 92% of the pantothenic acid was retained in the PL diet compared to only 71% in the FM diet.

4. Discussion

Trout diet formulations have changed considerably in the last ten years and modern diets reflect changing ingredient markets, feed processing technologies, and faster growing strains of trout. The content of fish meal in the feeds has decreased over this time period due to economic, environmental, and sustainability issues. Feed processing method has also changed from compression pellets to the higher temperature and pressure method of cooking extrusion, which has been shown to reduce levels of some vitamins. In contrast,

Table 3: Analyzed vitamin content of experimental diets after extrusion

| Vitamin, units/kg diet |Plant-meal based diets |Fish-meal based diets | NRC
<table>
<thead>
<tr>
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<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>None&lt;sup&gt;3&lt;/sup&gt;</td>
<td>NRC</td>
<td>VR</td>
</tr>
<tr>
<td>Vitamin A, IU</td>
<td>2820</td>
<td>4240</td>
<td>4530</td>
</tr>
<tr>
<td>Beta carotene, IU</td>
<td>2780</td>
<td>2950</td>
<td>3000</td>
</tr>
<tr>
<td>Total Vitamin A, IU</td>
<td>5600</td>
<td>7190</td>
<td>7530</td>
</tr>
<tr>
<td>Vitamin D, IU</td>
<td>3070</td>
<td>3890</td>
<td>5140</td>
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<tr>
<td>Vitamin E, mg</td>
<td>12.9</td>
<td>42.8</td>
<td>70.9</td>
</tr>
<tr>
<td>Folic acid, mg</td>
<td>0.6</td>
<td>1.9</td>
<td>2.6</td>
</tr>
<tr>
<td>Pantothenic acid, mg</td>
<td>4.3</td>
<td>23.1</td>
<td>25.8</td>
</tr>
<tr>
<td>Riboflavin, mg</td>
<td>2.7</td>
<td>6.6</td>
<td>6.7</td>
</tr>
<tr>
<td>Pyridoxine, mg</td>
<td>3.6</td>
<td>5.9</td>
<td>7.3</td>
</tr>
<tr>
<td>Thiamin, mg</td>
<td>5.7</td>
<td>6.2</td>
<td>7.1</td>
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Vitamin A, retinol 4050 2880 2820 4530 1710 59 87 a

when feeds contain oxidizing lipids are fed (Cowey et al., 1981; Larbey vitamin E due to its anti-oxidant and lipid soluble characteristics, crits and survival. Trout fed FM-ER diet compared to the FM-VR diet seemed to provide some

the values for trout fed the FM-ER. The increase in vitamin E content of

which were within the normal range, but still signiﬁcantly less than trout fed FM-NRC (31.5%)

Anemia, and the accumulation of ceroid in the liver, are signs often

seen with a vitamin E deﬁciency in ﬁsh (NRC, 1993). Various blood

chemistry test including erythrocyte fragility tests (Draper and Csallany, 1969) and peroxide hemolysis of red blood cells (Hung et

al., 1983) have been used to determine vitamin E status. Hematocrit values represent the abundance of red blood cells, and can be used to
diagnose anemia. Hematocrit values for trout fed FM-NRC were very

low (7.0%), and were signiﬁcantly less than trout fed FM-VR diet or any of the PL diets. A vitamin E deﬁciency is the suspected cause for this decrease in survival. Trout fed FM-None had signs of a vitamin E deﬁciency, with accumulation of ceroid pigment in livers, the anterior and posterior portions of the kidney as well as in spleens and severely depressed hematocrits.

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low (7.0%), and were signiﬁcantly less than trout fed FM-VR diet or any of the PL diets. A vitamin E deﬁciency is the suspected cause for this decrease in survival. Trout fed FM-None had signs of a vitamin E deﬁciency, with accumulation of ceroid pigment in livers, the anterior and posterior portions of the kidney as well as in spleens and severely depressed hematocrits.

Anemia, and the accumulation of ceroid in the liver, are signs often

seen with a vitamin E deﬁciency in ﬁsh (NRC, 1993). Various blood

chemistry test including erythrocyte fragility tests (Draper and Csallany, 1969) and peroxide hemolysis of red blood cells (Hung et

al., 1983) have been used to determine vitamin E status. Hematocrit values represent the abundance of red blood cells, and can be used to
diagnose anemia. Hematocrit values for trout fed FM-NRC were very

low (7.0%), and were signiﬁcantly less than trout fed FM-VR diet or any of the PL diets. A vitamin E deﬁciency is the suspected cause for this decrease in survival. Trout fed FM-None had signs of a vitamin E deﬁciency, with accumulation of ceroid pigment in livers, the anterior and posterior portions of the kidney as well as in spleens and severely depressed hematocrits.
The trout fed PL-NRC exhibited reduced growth within the first 3 weeks, and clubbed gills after 6 weeks, each of which could be attributed to a pantothenic acid deficiency (NRC, 1993). Pantothenic acid is a component of Coenzyme A, and is required in reactions to process energy from the carbon skeletons of amino acids, fatty acids, and glucose. In early studies conducted by McLaren et al. (1947) the pantothenic acid requirement was estimated to be between 10 and 20 mg/kg diet for rainbow trout. Cho and Woodward (1990) latter refined that estimate to 20 mg/kg diet based on growth response. While pantothenic acid deficiency was apparent in trout fed PL-None, a marginal deficiency may also have occurred in trout fed PL-NRC. Since pantothenic acid is involved in energy production, a marginal deficiency may be detected by reduced ERE. Trout fed PL-NRC had significantly lower ERE relative to trout fed PL-VR or PL-ER.

Kaushik et al. (1998) observed an interaction of vitamin level and protein source on protein utilization. An increase in protein efficiency ratio was reported with increasing vitamin content when feeding semi-purified diets, but not when fish meal based diets were fed. In contrast, increasing dietary vitamin levels in the current study did affect protein efficiency in FM diets, but not in PL diets. PEE was lower in the trout fed FM-NRC compared to trout fed FM-VR or FM-ER. Primary differences between the study by Kaushik et al. (1998) and the current study was that Kaushik et al. (1998) compared performance of trout fed semi-purified and fish meal based diets and the diets were produced by steam pelleting while only practical type diets were used in the present study and all feeds were produced by cooking extrusion. Histopathological evaluation of fish in this study indicated that pantothenic acid deficiency appears first in un-supplemented PL diets, and vitamin E deficiency signs appear first for trout fed un-supplemented FM diets, even though additional pathological changes of unknown cause were occurring. Hematocrit values seemed to be a more sensitive measurement of vitamin status than growth, or survival. There were significant differences in hematocrits for fish fed the diets with vitamin premix NRC compared to those fed diets with VR or ER, regardless of protein source. Hematocrit is an easy measurement of immediate vitamin status that could be used as a predictor of future growth performance.

In the present study the vitamin retention values reflect both processing and storage were very similar to values reported by Gadient and Fenster (1994), Marchetti et al. (1999), Li et al. (1996), Gabaudan and Hardy (2000b), Anderson and Sunderland (2002) except for vitamin A and thiamin. In the PL and FM diets only 59% and 83%, respectively, compared to 78% in the study by Gadient and Fenster (1994). Analyzed vitamin E levels in both the PL and FM diets supplemented with premix NRC were slightly lower than growth, or survival. There were significant differences in hematocrits for fish fed the diets with vitamin premix NRC compared to those fed diets with VR or ER, regardless of protein source. Hematocrit is an easy measurement of immediate vitamin status that could be used as a predictor of future growth performance.

References


Acknowledgements

We wish to thank ARS technicians April M. Teague and Lorrie Van Tassel, ARS SCEP student, G. Scott Snyder, and University of Idaho personnel Mike Casten for their assistance with this study. This study was funded by the USDA/Agricultural Research Service, Trout-Grains Project, # 5366-21310-003-00D.