

HUMAN NUTRITION

Title: Consumer acceptability and stability of omega-3 enriched pork products –
NPB number 09-066

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Industry summary

In this study the degree of DHA/EPA enrichment of pig tissues that can be achieved by feeding pigs a diet supplemented by different levels of Gromega, an algal source of DHA/EPA, while still retaining consumer acceptability was determined. As food products enriched with DHA/EPA may be susceptible to oxidation and rancidity this study also determined the stability of these products. It was found that increasing the amount of DHA/EPA in the pig's diet increased the amount of DHA/EPA in products made from these pigs (loins, frankfurters, bratwurst or sausage). Overall, supplementing the diet with 6% Gromega provided the most consistent results. Supplementing the diet with DHA/EPA had no effect on consumer acceptability of the pork products and no consistent effect on measures of oxidation or rancidity.

Keywords: Docosahexaenoic acid, Eicosapentaenoic acid, Enrichment, Pork, consumer acceptability

Scientific abstract

Pork loins from pigs that consumed a diet supplemented with 6% Gromega contained more EPA than the loins from pigs that had eaten a diet supplemented with 4%, 2% or 0% Gromega (6% > 4% > 2% = 0%). There was insufficient data to draw conclusions about the DHA content. The loin products from the pigs consuming a diet supplemented with 6% Gromega contained more vitamin E than the 4%, 2% or 0% products (6% > 4% = 2% = 0%). There was an effect of time on vitamin E content which was higher in samples at week 5 and 10 than week 0. The 6% and 0% products had a lower TBARS value than the 2% or the 4% loins and there was no effect of time on the TBARS value.

Frankfurter products made from the pigs that consumed a diet supplemented with 6% Gromega

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contained more EPA than the frankfurter products made from the pigs that consumed a diet supplemented with 4%, 2% or 0% Gromega (6% > 4% > 2% > 0%). There was an effect of time of EPA content and the frankfurter samples from week 10 contained more EPA than those from week 5 or 0. Frankfurter products made from pigs that consumed a diet supplemented with 6% Gromega contained more DHA than frankfurter products made from pigs that had consumed 4%, 2% or 0% Gromega (6% > 4% > 2% = 0%). There was an effect of time on DHA content of the products (week 10 > week 1 > week 5). There was no effect of feed supplementation level on vitamin E content of the frankfurter products. The TBARs value was highest in the 4% products and in the week 10 samples.

Bratwurst products made from pigs that consumed a diet supplemented with 6% Gromega contained more EPA than the bratwurst products from pigs that had consumed a diet supplemented with 4%, 2% or 0% Gromega (6% > 4% > 2% = 0%). Bratwurst products made from pigs that consumed a diet supplemented with 6% Gromega contained more DHA than the products made with pigs that had consumed a diet supplemented with 4%, 2%, 0% Gromega (6% > 4% > 2% > 0%). There was an effect of time on DHA content of the bratwurst products and levels were higher in the week 5 and 10 samples than the week 0 products (week 10 = week 5 > week 0). Vitamin E content was higher in bratwurst products made from pigs that consumed a diet supplemented with 6% Gromega than in bratwursts made from pigs that consumed a diet supplemented with 4%, 2% or 0% Gromega (6% > 4% = 2% > 0%). There was an effect of time on vitamin E content of the bratwursts with vitamin E content being higher in the week 0 and 10 samples than the week 5 samples (week 0 = week 10 > week 5). The TBARS value was lower in the bratwurst products made from pigs that consumed a diet supplemented with 2% Gromega than in the bratwurst products made from pigs that consumed a diet supplemented with 6%, 4% or 0% Gromega (2% < 6% = 4% = 0%). There was no effect of time on TBARS values.

Sausage products made from pigs that consumed a diet supplemented with 6% Gromega contained more EPA than the sausage products made from pigs that consumed a diet supplemented with 4%, 2%, or 0% Gromega (6% > 4% > 2% > 0%). There was no effect of time on the EPA content of the sausages. Sausage products made from pigs that consumed a diet supplemented with 6% Gromega contained more DHA than sausage products made from pigs that consumed a diet supplemented with 4%, 2% or 0% Gromega (6% > 4% > 2% > 0%). There was no effect of time on the DHA content of the sausages. The vitamin E content of the sausages was not consistent across the different products. The TBARS value was highest in the sausage products made from pigs that consumed a diet supplemented with 6% Gromega than in the sausage products made from pigs that consumed a diet supplemented with 4%, 2% or 0% Gromega (6% > 4% = 2% > 0%). There was an effect of time on the TBARS value and the TBARS value was higher in the week 0 and 10 products than the week 5 products (Week 0 + week 10 > week 5).

Current American Heart Association recommendations are to consume between 0.5g and 1.8g of DHA and EPA each day. As the recommended intake of meat each day is 90g this amount could only reliably be reached by consumption of the products made from pigs whose feed had been supplemented with 6% Gromega.

Introduction

Accumulating evidence indicates that regular consumption of the long-chain omega-3 fatty acids eicosapentaenoic acid (EPA; 20:5*n*-3) and docosahexaenoic acid (DHA; 22:6*n*-3) reduces risk of developing coronary heart disease. Consequently, several health groups recommend individuals to increase their intake of EPA and DHA. These efforts have been hampered because DHA/EPA are largely obtained from marine sources which may not be widely available, be expensive or lack consumer acceptance due to taste or concerns about environmental toxins. Due to the potential health benefits of increased consumption of EPA/DHA there is a need for alternative sources. One strategy is the enrichment of other animal foods by feeding them a diet supplemented with a DHA/EPA supplement derived from algal or marine sources. Previous research indicates that this strategy can be used to enrich meat products with DHA/EPA and that regular consumption of these products improves risk factors associated with coronary heart disease. Concerns remain about this approach as these products may be tainted with off-flavors as a result of being enriched with marine derived fatty acids or due to oxidation of the polyunsaturated omega-3 fatty acids. As this approach to increasing the populations intake of EPA/DHA could provide public health benefits and add value to pork products research is required to demonstrate its feasibility

Objectives

This study will determine the degree of DHA/EPA enrichment of pig tissues that can be achieved by feeding finisher pigs a diet supplemented by different levels of Gromega, an algal source of DHA/EPA, while still retaining consumer acceptability. As pork products enriched with DHA/EPA may be susceptible to oxidation and rancidity this study will determine the stability of these products. The specific aims of this study are:

- 1) To determine the degree of enrichment that can be achieved by feeding pigs a diet supplemented with different levels of Gromega
- 2) To determine the stability of pork products made from pigs that consumed a diet supplemented with different levels of Gromega
- 3) To determine the consumer acceptability of pork products made from pigs that consumed a diet supplemented with different levels of Gromega

Materials & Methods

12 finisher pigs were split into four groups: 0% Gromega, 2% Gromega, 4% Gromega and 6% Gromega. These pigs consumed a standard diet supplemented with the relevant amount of Gromega for eight weeks before slaughter. Following slaughter, the carcasses were processed in the Iowa State University meat processing laboratory to produce pork loins, bratwurst, frankfurters and breakfast sausages. Four versions of each product were produced (0%, 2%, 4% and 6% Gromega). The product formulations for the four products are provided in appendix one. The products were vacuum packed and frozen at -20°C. Samples of each meat cut were tested for EPA/DHA, vitamin E content and a TBARS assay conducted following freezing for one week, five weeks and ten weeks.

Determination of EPA/DHA content of enriched pork products

Duplicate samples of uncooked processed pork products derived from control and Gromega supplemented pigs were analyzed for fatty acid content. The pork products were homogenized and transesterified to extract the lipids as fatty acid methyl esters. An internal standard (23:0; Sigma-Aldrich) was added to 200 mg pork homogenized in 3 mL chloroform/methanol (2 : 1, vol/vol) and 1 ml BHT (15 mg/L). Of the homogenate, 150 mL was transferred into 2 mL methanol/toluene (4 : 1, vol/vol) and the fatty acids transesterified. The upper toluene phase containing the fatty acid methyl esters were removed and analyzed by flame ionization gas chromatography. Individual fatty acids were identified by comparison with known standards. Fatty acids were converted from fatty acid methyl esters into mg/100 g by comparison to an internal standard (23:0) and then adjusted using a lipid conversion factor of 0.956. This process was conducted using uncooked pork products that were frozen for 1, 5 and 10 weeks.

Susceptibility to oxidation

Duplicate samples of the Frankfurter, bratwurst, sausage and loin were analyzed for lipid oxidation using a TBARS test. Results were adjusted for water content in fresh meat and expressed as mg of malondialdehyde equivalents per kg. This process was conducted using uncooked pork products that were frozen for 1, 5 and 10 weeks.

Determination of Vitamin E content

Duplicate samples of each of the Frankfurter, bratwurst, sausage and loin were analyzed for vitamin E content. This process was conducted on uncooked and cooked pork products after being frozen for 1, 5 and 10 weeks. Alpha-tocopherol and 5 α -cholestane were purchased from Sigma Chemical Co. (St. Louis, Mo., U.S.A.). Sylon BFT [Bis-(trimethylsilyl) trifluoroacetamide (BSTFA) + trimethylchlorosilane (TMCS) = 99:1] was obtained from Supelco (Bellefonte, Pa., U.S.A.). Hexane (HPLC grade) and pyridine was obtained from Fisher Scientific (Fair Lawn, N.J., U.S.A.). Ground meat (2 g) was accurately weighed into a 50-mL screw-cap test tube, and then 10 mL of saponification reagent prepared by freshly mixing ethanol and 33% (w/v) KOH solution at a ratio of 94:6, 0.5 mL of 20% ascorbic acid (to prevent oxidation of tocopherols during saponification), and 50 μ L of 5 α -cholestane solution (1 μ g/ μ L in hexane) were added immediately. The sample was homogenized with a polytron for 5 s at full speed, capped, and then incubated for 1 hour at 50°C. After cooling in ice water for 10 min, 5 mL deionized distilled water and 3 mL hexane were added. Tubes were capped tightly and then the contents were mixed thoroughly by shaking. After 15 hours for phase separation, the hexane layer containing unsaponifiables was carefully transferred to a scintillation vial and dried under nitrogen flow. To the dried sample 200 μ L pyridine and 100 μ L Sylon BFT (99% BSTFA + 1% TMCS) were added. The sample was derivatized either at 50 °C in a water bath for 1 hour. Analysis of tocopherols was performed with a Hewlett-Packard (HP) 6890 gas chromatography (GC) equipped with an on-column capillary injector and a FID detector (Hewlett-Packard Co., Wilmington, Del., U.S.A.). A 0.25-mm (i.d.) x 30-m Supelco Equity-5 (bonded 5% diphenyl and 95% dimethylsiloxane phase) column was used. A splitless inlet was used to inject samples (1 mL) into the capillary column; and ramped oven temperature was used (from 260 °C increased to 283 °C @ 1 °C /min). Inlet temperature was 300 °C, and the detector temperature was 320 °C. Helium was the carrier gas at constant flow of 0.9 mL/min. Detector (FID) air, H₂, and make-up gas (He) flows were 450 mL/min, 40 mL/min, and 39 mL/min, respectively. The area of each peak (pA*sec) was integrated using the ChemStation software (Hewlett-Packard Co., Wilmington, Del., U.S.A.) and the amounts of tocopherols and sterols were calculated using an internal standard, 5 α -cholestane. This process was conducted using uncooked pork products that were frozen for 1, 5 and 10 weeks.

Sensory evaluation of enriched pork products

Sensory tests were conducted to determine the consumer acceptability of the frankfurter, bratwurst, sausage and loin products. Each product will be tested at the four different levels of enrichment (0, 2, 4 and 6%). The sensory testing will take place at one time point (after 5 weeks frozen storage). Each test will use 50 individuals who are regular purchasers and consumers of pork. Consumers will be asked questions pertaining to overall acceptability, acceptability of tenderness, juiciness and flavor and purchase/consumption intent. The consumer acceptability studies will be conducted in specialized sensory analysis facilities. Sensory analysis was conducted on products that had been frozen for five weeks.

Statistical analysis

Means and standard deviations were calculated for all study variables. Differences between supplementation level and changes with time were determined using ANOVA followed by a Bonferroni post hoc test. All statistical analysis was conducted using SPSS v17 for windows (SPSS, IL).

Results

EPA/DHA content of pork products

Loin

Figure one provides data regarding the EPA content of the loin samples in weeks 0, 5 and 10. There was a significant main effect of feed supplementation on EPA content of the loin products ($F(3,24)=55.426$, $p<0.05$). Post hoc analysis revealed that the loins from the pig whose diet was supplemented with 6% Gromega was higher than the 4% loins which was higher than the 2% loins ($p<0.05$). There was no statistically significant difference in the EPA content of the 0% and 2% loin products.

There was a significant main effect of time on EPA content of the loin products ($F(3,24)=5.369$, $p<0.05$). Post hoc analysis revealed that EPA contents of the loin products were higher at week 10 than week 0 or 5 ($p<0.05$).

There was no statistically significant interaction between the level of feed supplementation and time ($F(6,24)=0.729$, $p>0.05$).

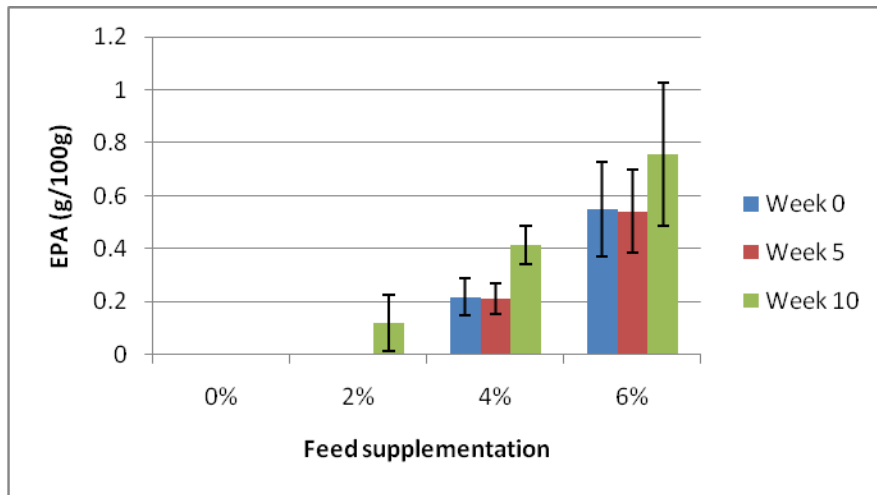


Figure one – the EPA content of pork loin products

Figure two provides data regarding the DHA content of the pork loin samples. The DHA content of the pork loin products was not consistent and no statistical analysis was performed.

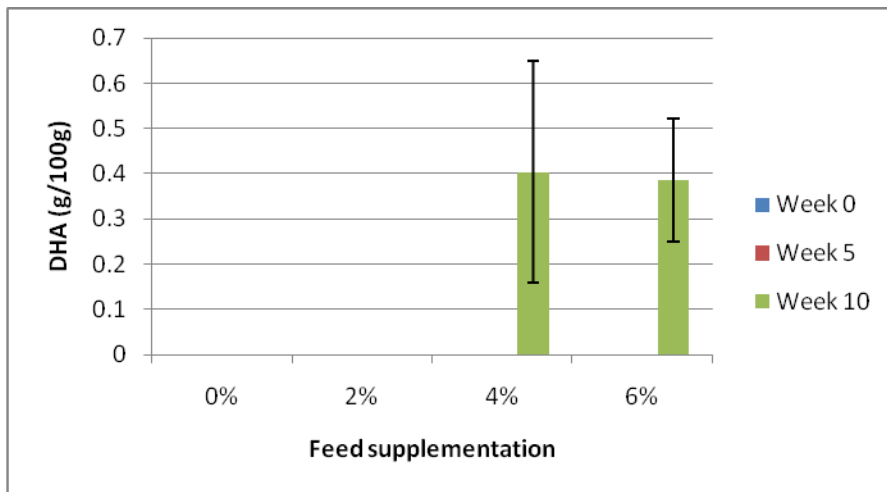


Figure two – the DHA content of pork loin products

Frankfurters

Figure three provides data regarding the EPA content of the frankfurter samples in weeks 0, 5 and 10. There was a significant main effect of level of feed supplementation on the EPA content of the frankfurter products ($F(3,24)=69.914, p<0.05$). Post hoc analysis revealed that the 6% feed supplement was higher than the 4% which was higher than the 2% ($p<0.05$).

There was a significant main effect of time on EPA content of the frankfurter products ($F(3,24)=19.536, p<0.05$). Post hoc analysis revealed that EPA content in the frankfurter products were highest at week 10 ($p<0.05$). EPA content was higher during week 1 than in week 5 ($p<0.05$).

There was a statistically significant interaction between feed supplementation and time ($F(6,24)=3.356, p>0.05$).

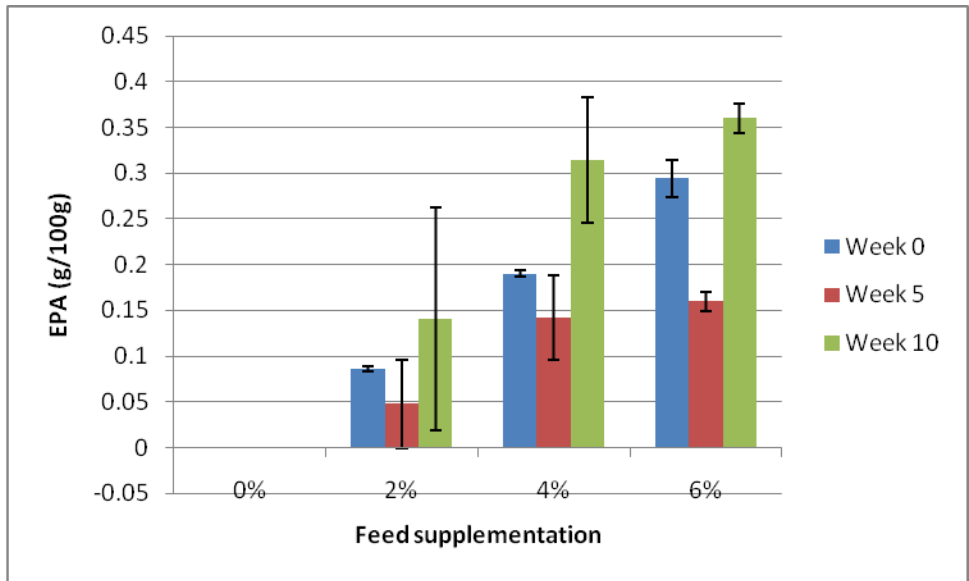


Figure three- EPA content of the frankfurter products

Figure four provides data regarding the DHA content of the frankfurter samples in weeks 0, 5 and 10. There was a significant main effect of feed supplementation on DHA content of the frankfurter products ($F(3,24)=103.362, p<0.05$). Post hoc analysis revealed that the 6% feed supplement was higher than the 4% ($p<0.05$). There was no measureable DHA in the 2% or 0% frankfurter products.

There was a significant main effect of time on DHA content of the frankfurter products ($F(3,24)=36.169, p<0.05$). Post hoc analysis revealed that DHA content in the frankfurter products were highest at week 10 ($p<0.05$). DHA content was higher during week 1 than in week 5 ($p<0.05$).

There was a statistically significant interaction between feed supplementation and time ($F(6,24)=13.562, p>0.05$).

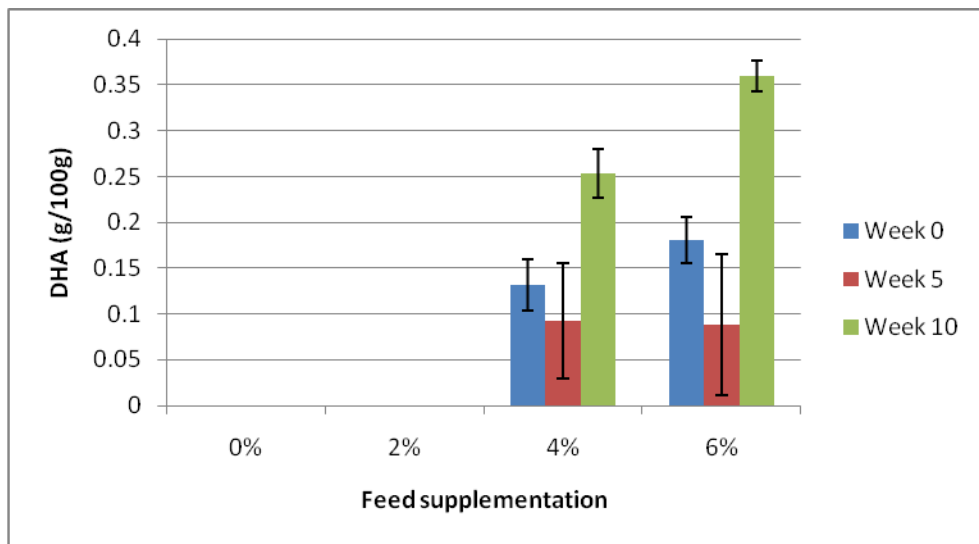


Figure four - DHA content of the frankfurter products

Bratwurst

Figure five provides data regarding the EPA content of the Bratwurst samples in weeks 0, 5 and 10. There was a significant main effect of feed supplementation on EPA content of the Bratwurst products ($F(3,24)=180.899$, $p<0.05$). Post hoc analysis revealed that the 6% feed supplement was higher than the 4% ($p<0.05$) which was greater than 2% and 0%. There was no difference between 2% and 0% products.

There was a significant main effect of time on EPA content of the bratwurst products ($F(3,24)=252.779$, $p<0.05$). Post hoc analysis revealed that EPA content in the bratwurst products were highest at week 5 than week 1 ($p<0.05$).

There was a statistically significant interaction between feed supplementation and time ($F(6,24)=48.738$, $p>0.05$).

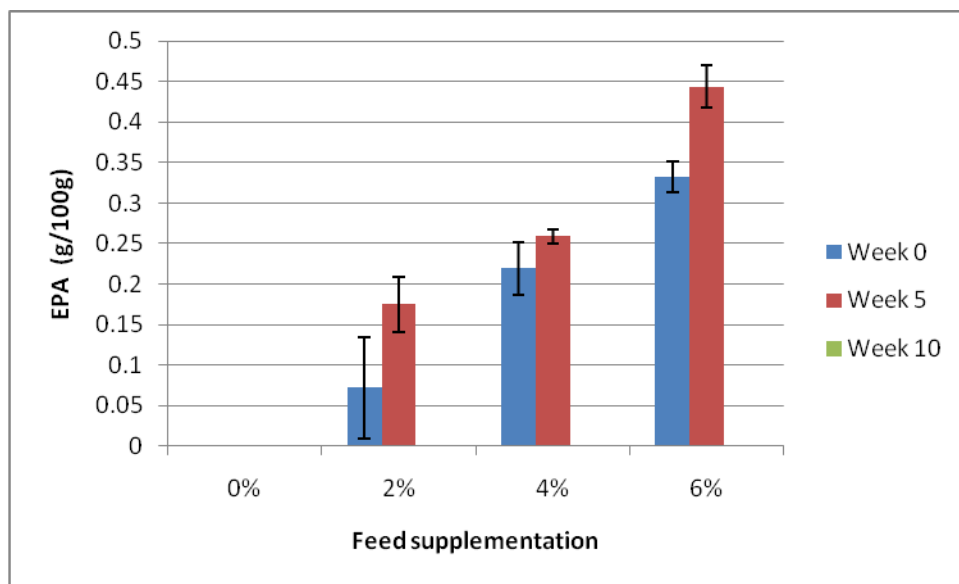


Figure five – EPA content of the bratwurst products

Figure six provides data regarding the DHA content of the bratwurst samples in weeks 0, 5 and 10. There was a significant main effect of feed supplementation on DHA content of the Bratwurst products ($F(3,24)=227.668$, $p<0.05$). Post hoc analysis revealed that the 6% feed supplement was higher than the 4% which was higher than 2% ($p<0.05$).

There was a significant main effect of time on DHA content of the bratwurst products ($F(3,24)=8.698$, $p<0.05$). Post hoc analysis revealed that DHA content in the bratwurst products were higher at week 5 and 10 than week 1 ($p<0.05$). There was no statistically significant difference between week 5 and week 10.

There was a statistically significant interaction between feed supplementation and time ($F(6,24)=7.132$, $p>0.05$).

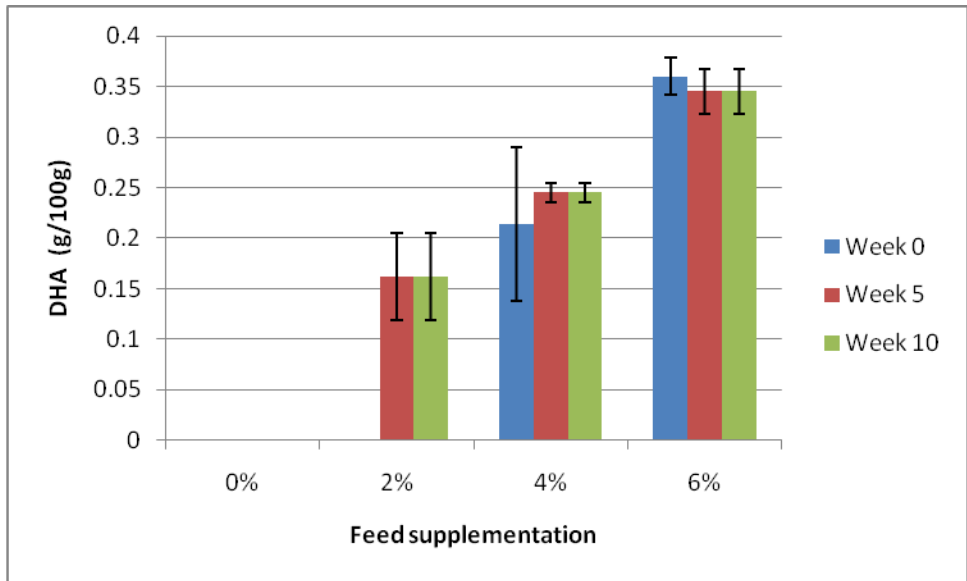


Figure six – DHA content of the bratwurst products

Sausage

Figure seven provides data regarding the EPA content of the sausage samples in weeks 0, 5 and 10. There was a significant main effect of feed supplementation on EPA content of the sausage products ($F(3,24)=29.194, p<0.05$). Post hoc analysis revealed that the 6% feed supplement was higher than the 4% which was higher than 2% ($p<0.05$). There was no statistically significant difference between the 2% and 0% samples.

There was no significant main effect of time on EPA content of the sausage products ($F(3,24)=0.320, p>0.05$).

There was no statistically significant interaction between feed supplementation and time ($F(6,24)=0.407, p>0.05$).

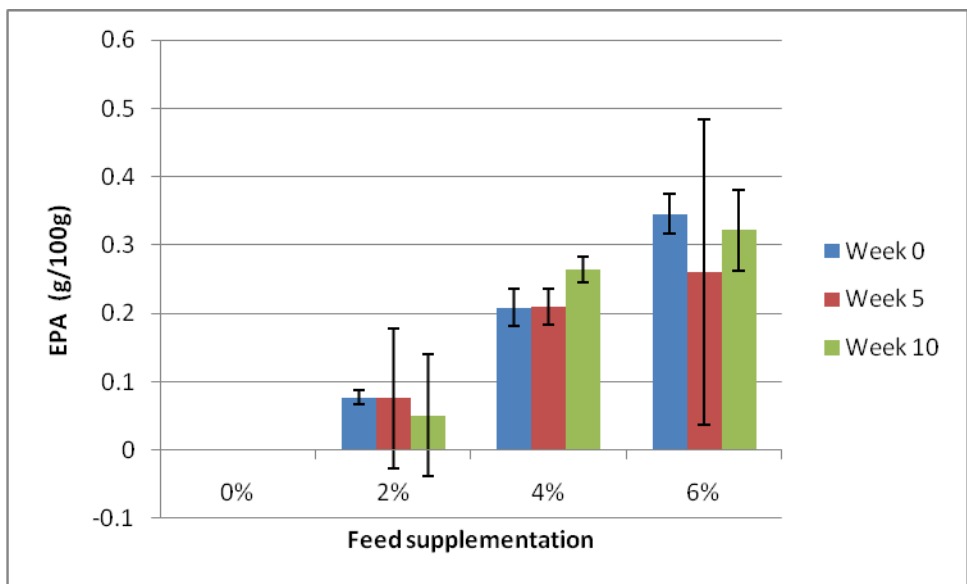


Figure seven – EPA content of the sausage products

Figure eight provides data regarding the DHA content of sausage patty products. There was a significant main effect of feed supplementation on DHA content of the sausage products ($F(3,24)=28.486$, $p<0.05$). Post hoc analysis revealed that the 6% and 4% feed supplement which was higher than 2% or 0% ($p<0.05$). There was no statistically significant difference between the 6% and 4% sausage samples. There was no measureable amount of DHA in the 2% samples.

There was no significant main effect of time on DHA content of the sausage products ($F(3,24)=1.751$, $p>0.05$).

There was no statistically significant interaction between feed supplementation and time ($F(6,24)=1.149$, $p>0.05$).

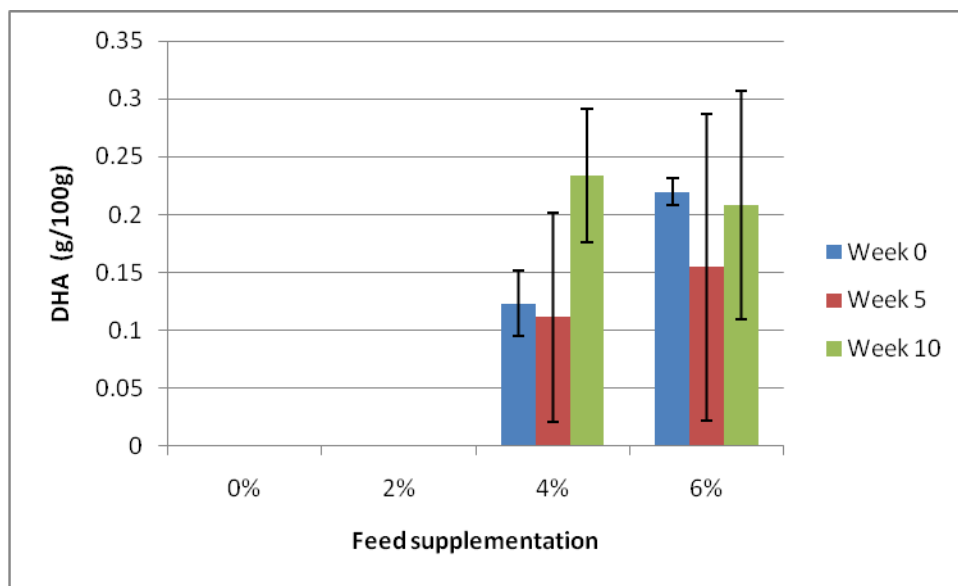


Figure eight – DHA content of the sausage products

Total DHA +EPA

Table one provides the total amount of EPA and DHA provided by 100g of each product. Current American Heart Association recommendations are to consume between 0.5g and 1.8g of DHA and EPA each day. As the recommended intake of meat each day is 90g this amount could only reliably be reached by consumption of the products made from pigs whose feed had been supplemented with 6% Gromega.

| | 0% | 2% | 4% | 6% |
|---------------------|----|------|------|------|
| Loin | | | | |
| Week 1 | 0 | 0 | 0.22 | 0.54 |
| Week 5 | 0 | 0 | 0.21 | 0.54 |
| Week 10 | 0 | 0.12 | 0.81 | 0.14 |
| Frankfurters | | | | |
| Week 1 | 0 | 0.09 | 0.32 | 0.47 |
| Week 5 | 0 | 0.05 | 0.23 | 0.15 |
| Week 10 | 0 | 0.14 | 0.56 | 0.72 |
| Bratwurst | | | | |
| Week 1 | 0 | 0.07 | 0.43 | 0.69 |
| Week 5 | 0 | 0.35 | 0.51 | 0.79 |
| Week 10 | 0 | 0.16 | 0.25 | 0.34 |
| Sausage | | | | |
| Week 1 | 0 | 0.07 | 0.33 | 0.56 |
| Week 5 | 0 | 0.07 | 0.35 | 0.48 |
| Week 10 | 0 | 0.05 | 0.5 | 0.53 |

Table one – total EPA and DHA content of the pork products

TBARS assay

Loins

Figure nine provides data regarding the TBARS value of the loin products. There was a significant main effect of feed supplementation on the TBARS value of the loin products ($F(3,60)=8.637$, $p<0.05$). Post hoc analysis revealed that the 6% and 0% feed supplement which was lower than the 2% or 4% products ($p<0.05$).

There was no significant main effect of time on TBARS value of the loin products ($F(3,24)=3.318$, $p>0.05$).

There was a statistically significant interaction between feed supplementation and time ($F(6,24)=3.700$, $p<0.05$).

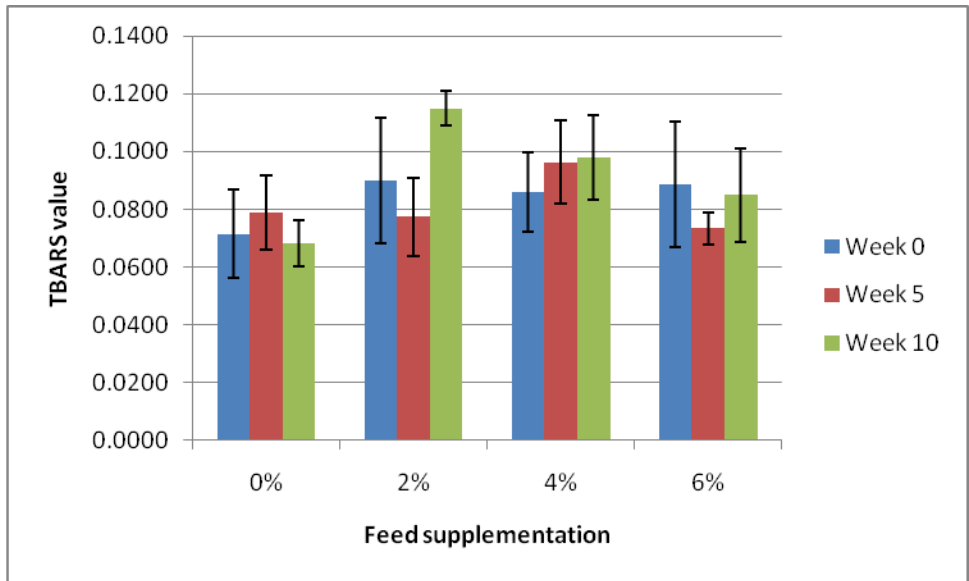


Figure nine – TBARS value of loin products

Bratwursts

Figure ten provides data regarding the TBARS value of the bratwurst products. There was a significant main effect of feed supplementation on the TBARS value of the loin products ($F(3,60)=3.307, p<0.05$). Post hoc analysis revealed that the 2% products had a lower TBARS value than the 4% and 6% products ($p<0.05$).

There was no significant main effect of time on TBARS value of the loin products ($F(3,24)=2.160, p>0.05$).

There was no statistically significant interaction between feed supplementation and time ($F(6,24)=1.327, p>0.05$).

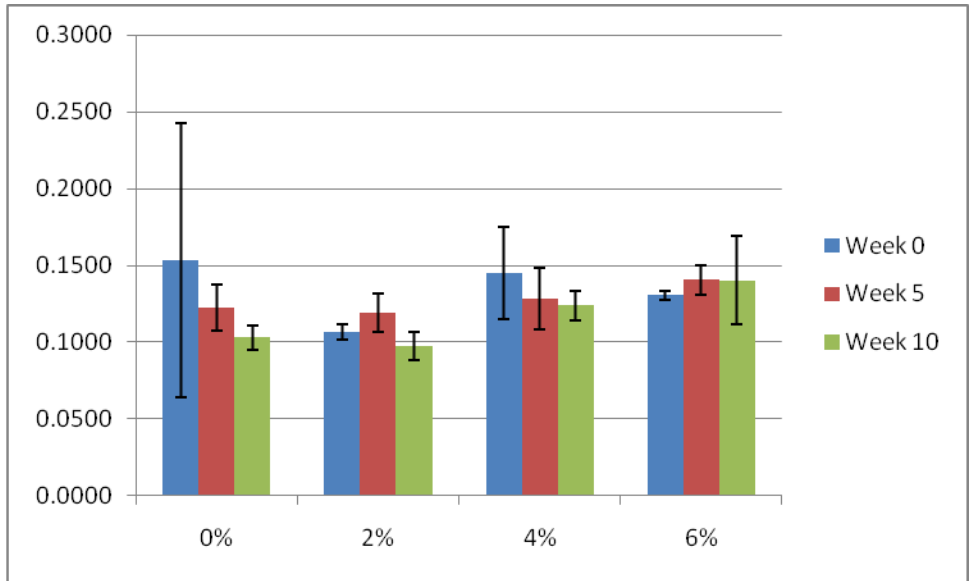


Figure ten – TBARS value of bratwurst products

Frankfurters

Figure eleven provides data regarding the TBARS value of the frankfurter products. There was a significant main effect of feed supplementation on the TBARS value of the frankfurter products ($F(3,60)=5.997, p<0.05$). Post hoc analysis revealed that the 4% products had a lower TBARS value than the 0%, 2% or 6% products ($p<0.05$).

There was a significant main effect of time on TBARS value of the frankfurter products ($F(3,24)=22.354, p>0.05$). Post hoc analysis revealed that TBARS value was higher at week 10 than at week 0 or 5 ($p<0.05$).

There was no statistically significant interaction between feed supplementation and time ($F(6,24)=4.206, p>0.05$).

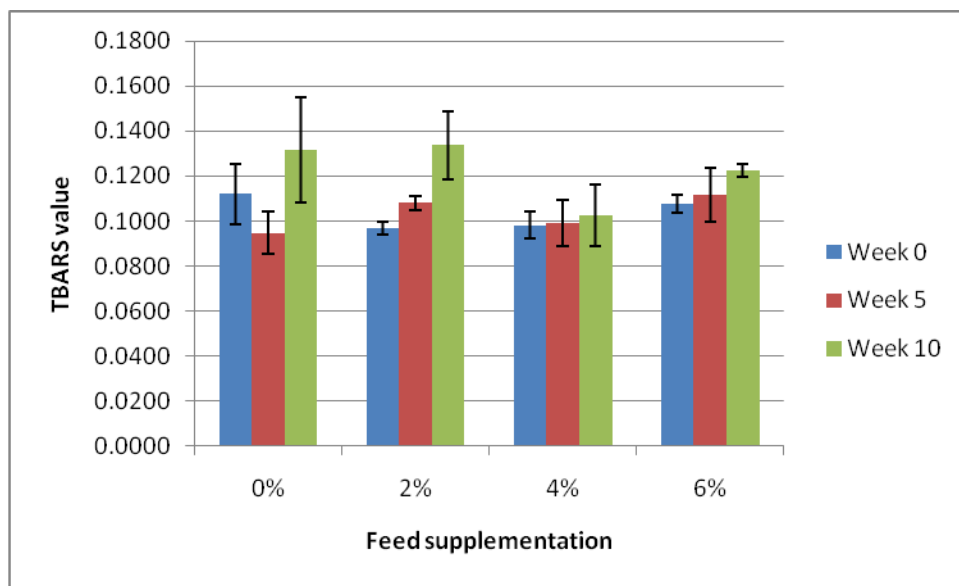


Figure eleven – TBARS value of frankfurter products

Sausages

Figure twelve provides data regarding the TBARS value of the sausage products. There was a significant main effect of feed supplementation on the TBARS value of the sausage products ($F(3,60)=33.756, p<0.05$). Post hoc analysis revealed that the 6% products had a higher TBARS value than the 0%, 2% or 4% products ($p<0.05$). The 2% and 4% had a higher TBARS than the 0% ($p<0.05$).

There was a significant main effect of time on TBARS value of the sausage products ($F(3,24)=11.682, p<0.05$). Post hoc analysis revealed that TBARS value was higher at week 0 and week 10 than at week 5 ($p<0.05$).

There was a statistically significant interaction between feed supplementation and time ($F(6,24)=2.610, p<0.05$).

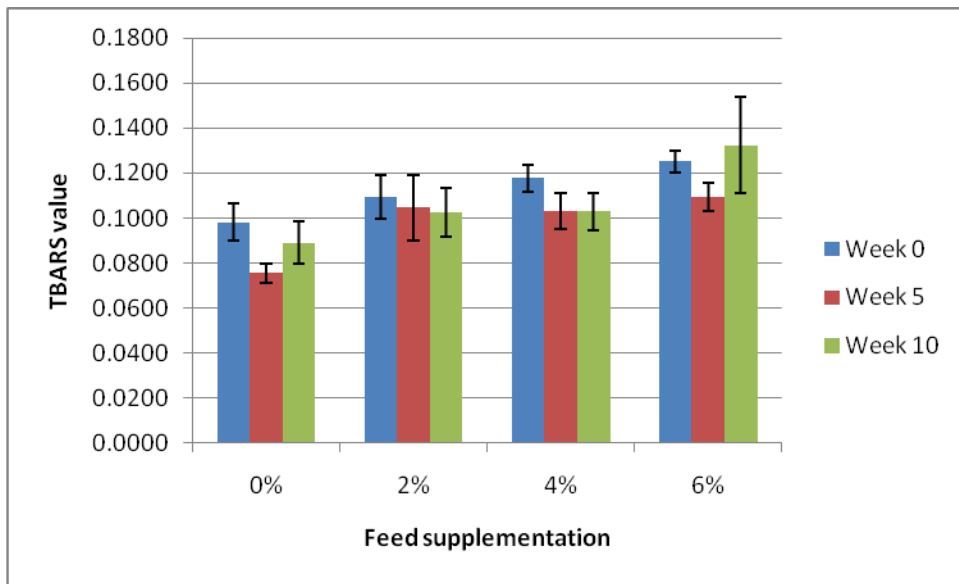


Figure twelve - TBARS value of sausage products

Vitamin E content

Loins

Figure thirteen provides data regarding the alpha-tocopherol content of the loin products. There was a significant main effect of feed supplementation on the vitamin E content of the loin products ($F(3,12)=19.217, p<0.05$). Post hoc analysis revealed that the 6% products had a higher vitamin E content than the 0%, 2% or 4% products ($p<0.05$).

There was a significant main effect of time on vitamin E content of the loin products ($F(2,12)=88.015, p<0.05$). Post hoc analysis revealed that vitamin E content was lower at week 0 than week 5 or 10 ($p<0.05$).

There was a statistically significant interaction between feed supplementation and time ($F(6,12)=4.694, p<0.05$).

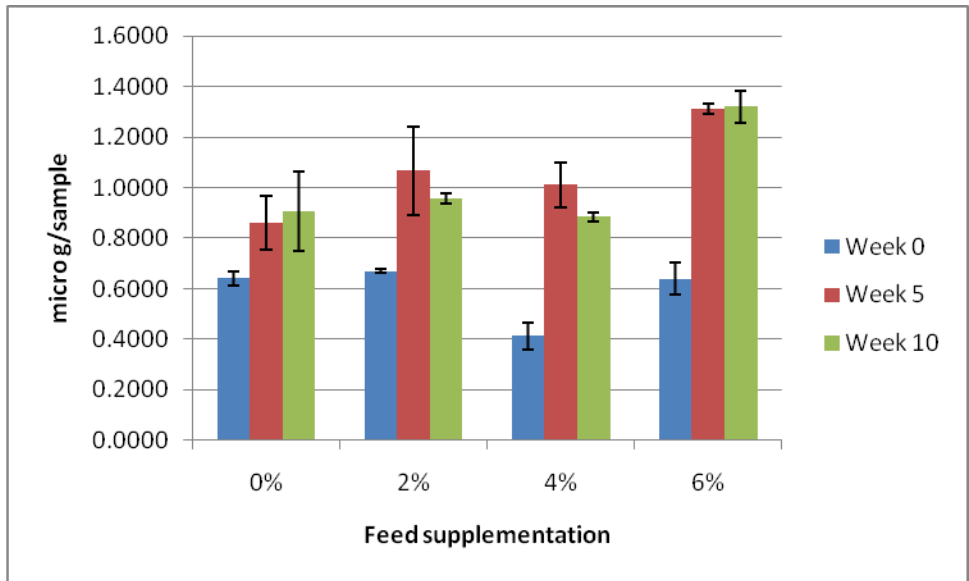


Figure thirteen – vitamin E content of the loin products

Bratwursts

Figure fourteen provides data regarding the vitamin E content of the bratwurst products. There was a significant main effect of feed supplementation on the vitamin E of the loin products ($F(3,12)=12.558$, $p<0.05$). Post hoc analysis revealed that the 6% products had a higher vitamin E than the 0%, 2% or 4% products ($p<0.05$). Moreover, the 4% products had a higher vitamin E content than the 0% ($p<0.05$).

There was a significant main effect of time on vitamin E content of the loin products ($F(2,12)=5.222$, $p<0.05$). Post hoc analysis revealed that vitamin E content was lower at week 5 than week 0 or 10 ($p<0.05$).

There was no statistically significant interaction between feed supplementation and time ($p>0.05$).

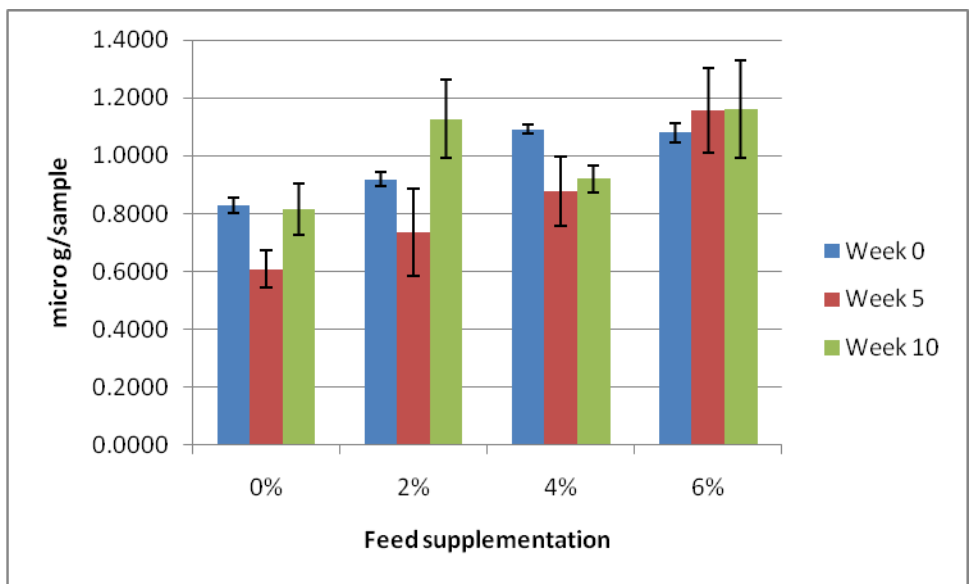


Figure fourteen – vitamin E content of the bratwurst

Frankfurters

Figure fifteen provides data regarding the vitamin E content of the frankfurters products. There was no statistically significant effect of feed supplementation, time or a supplement x time interaction ($p > 0.05$).

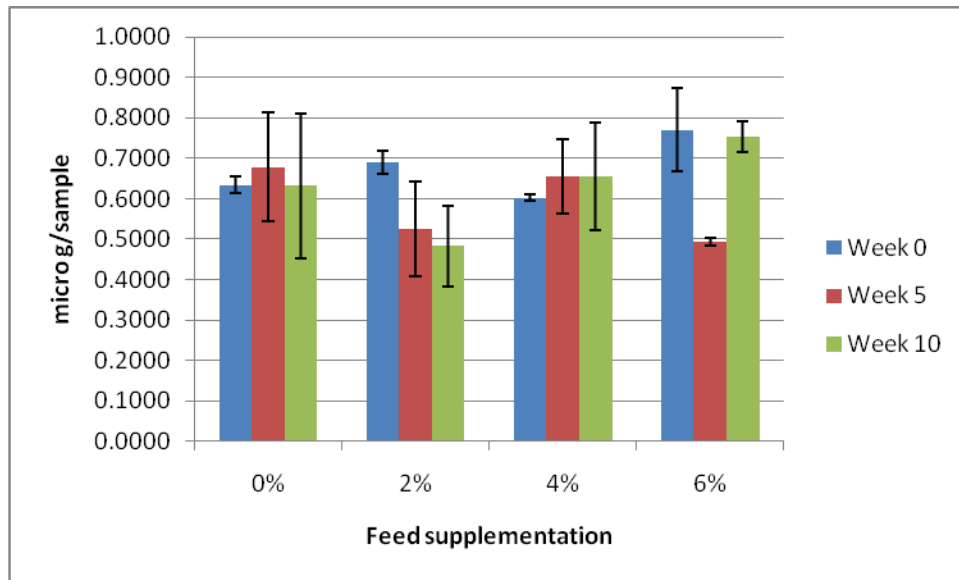


Figure fifteen – vitamin E content of the frankfurters

Sausages

Figure sixteen provides data regarding the vitamin E content of the sausage products. There was a significant main effect of feed supplementation on the vitamin E of the loin products ($F(3,12)=5.558$, $p < 0.05$). Post hoc analysis revealed that the 0% products had a higher vitamin E content than the 4% products ($p < 0.05$).

There was no significant main effect of time on vitamin E content value of the sausage products ($p > 0.05$).

There was a statistically significant interaction between feed supplementation and time ($F(6,12)=3.609$, $p < 0.05$).

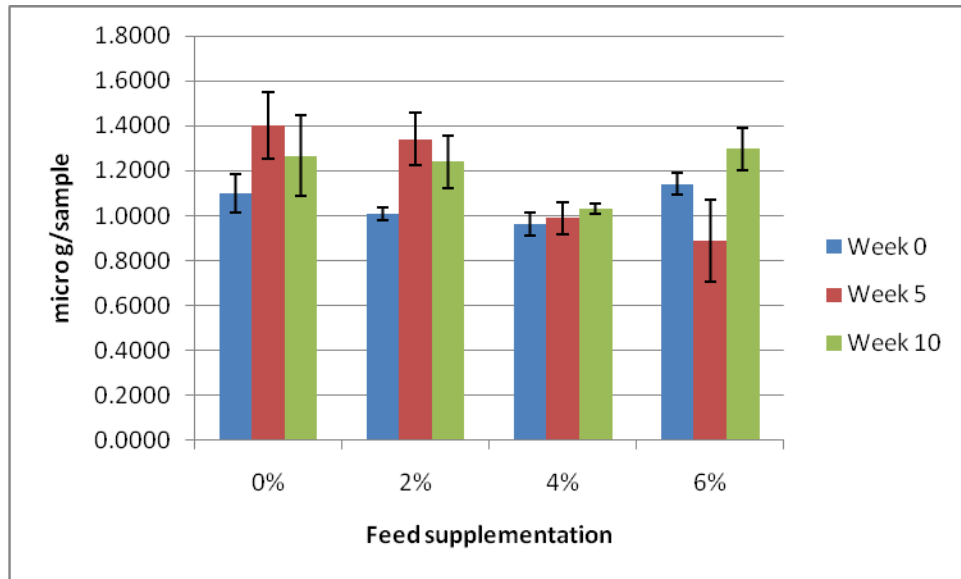


Figure sixteen – vitamin E content of the sausages

Sensory analysis

Loin

Fifty adults participated in the sensory analysis of the loin products. Twenty four of the participants were male and twenty six were female. The age distribution is provided in table two.

| Age (years) | 18-24 | 25-34 | 35-44 | 45-54 | 55-64 | >65 |
|-------------|-------|-------|-------|-------|-------|-----|
| n | 10 | 12 | 5 | 13 | 9 | 1 |

Table two – the age distribution of the participants

The frequency of pork product consumption of the study population is provided in table three.

| Frequency | >1/week | 1 per week | one every other week | once per month | < once month |
|-----------|---------|------------|----------------------|----------------|--------------|
| n | 9 | 20 | 14 | 6 | 1 |

Table three – the frequency of pork product consumption of the study population

The study population were asked to rate their overall rating of the pork loin products (figure seventeen). There was no significant difference in the participants hedonic rating of the different pork products ($p > 0.05$).

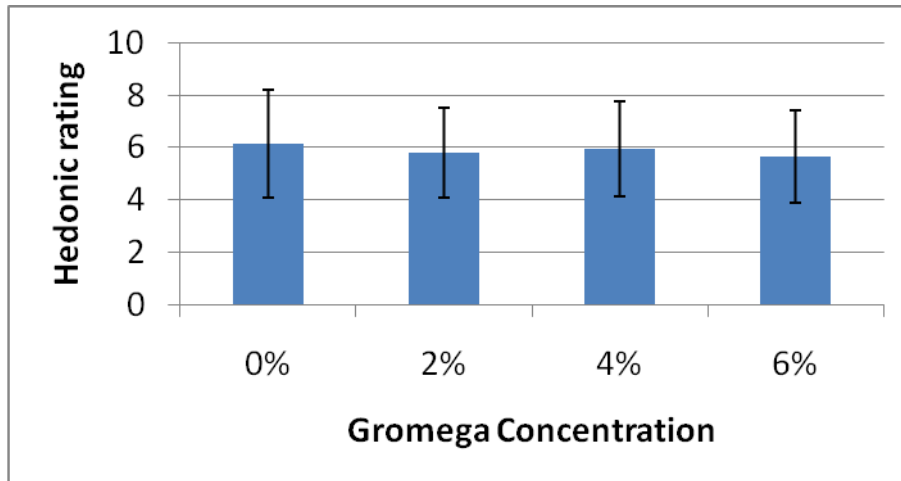


Figure seventeen – hedonic rating of the pork loin products

The participants were asked to rate the juiciness of the four pork loins (figure eighteen). There was no significant difference in the participants rated juiciness of the pork loin ($p > 0.05$).

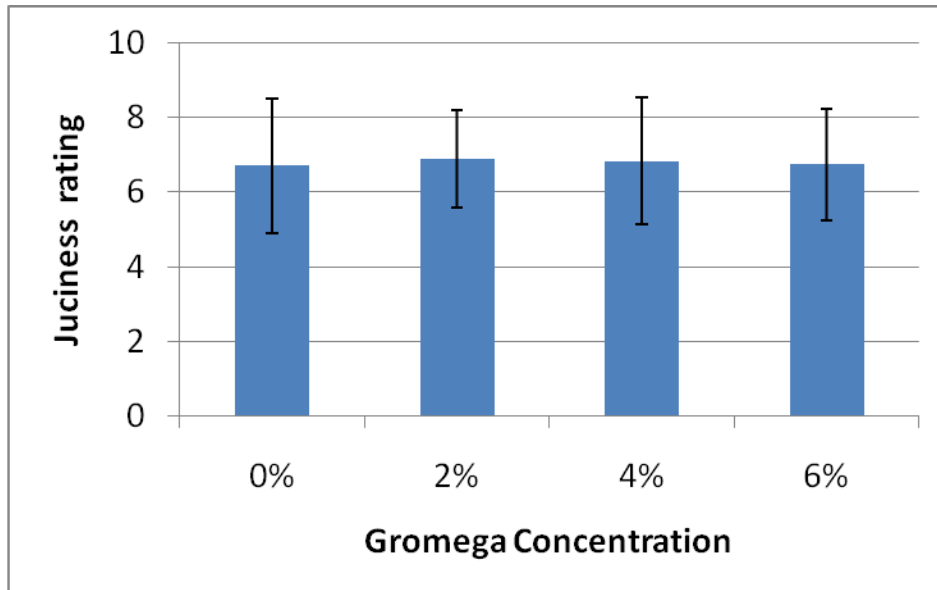


Figure eighteen – juiciness rating of the pork loin products

The participants were asked to rate the tenderness of the four pork loins (figure nineteen). There were no statistically significant differences in the rated tenderness of the pork loin samples ($F(3,49) = 2.01$; $p = 0.1$).

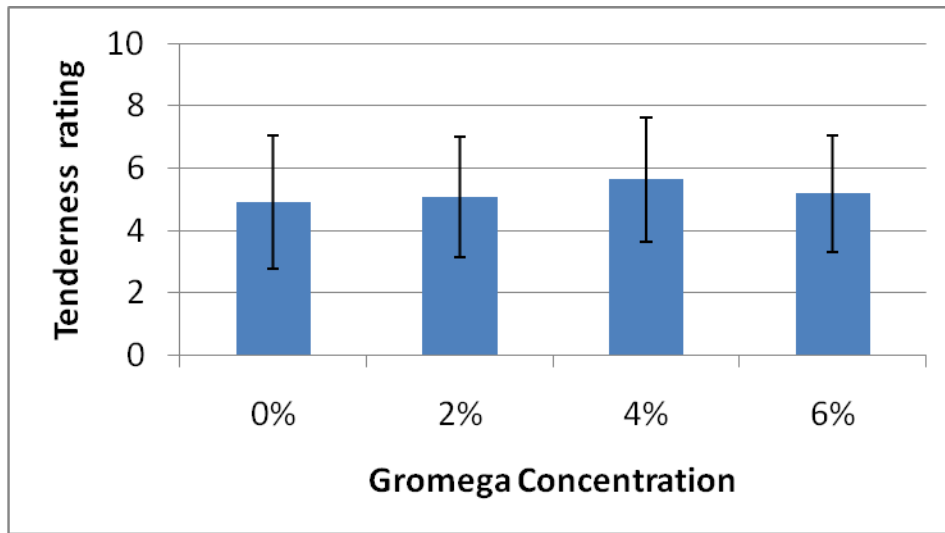


Figure nineteen – tenderness rating of the pork loin products

The participants were asked to rate the pork flavor of the four pork loin products (figure twenty). There were no statistically significant differences in the rated pork flavor of the pork loin samples ($F(3,49) = 2.10$; $p=0.1$).

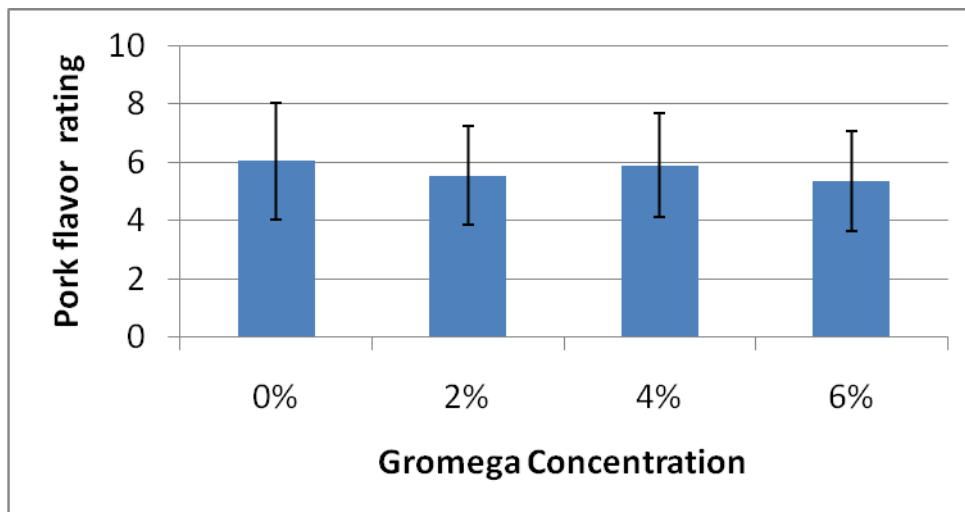


Figure twenty – pork flavor rating of the pork loin products

Participants were asked if they could detect an off flavor in the pork product they tasted (table four). There were no statistically significant differences between the products in terms of detected off flavors ($p>0.05$)

| Sample | 0% | 2% | 4% | 6% |
|-------------------------------|----|----|----|----|
| % detect off flavor | 24 | 40 | 36 | 32 |
| % could not detect off flavor | 76 | 60 | 64 | 68 |

Table four - % of participants who could detect an off flavor in the pork products

For individuals who detected an off flavor they were asked to rate the intensity of the off-flavor (figure twenty one). There were no significant difference in the rated intensity of the off flavors ($F(3,33) = 1.08$; $p=0.37$).

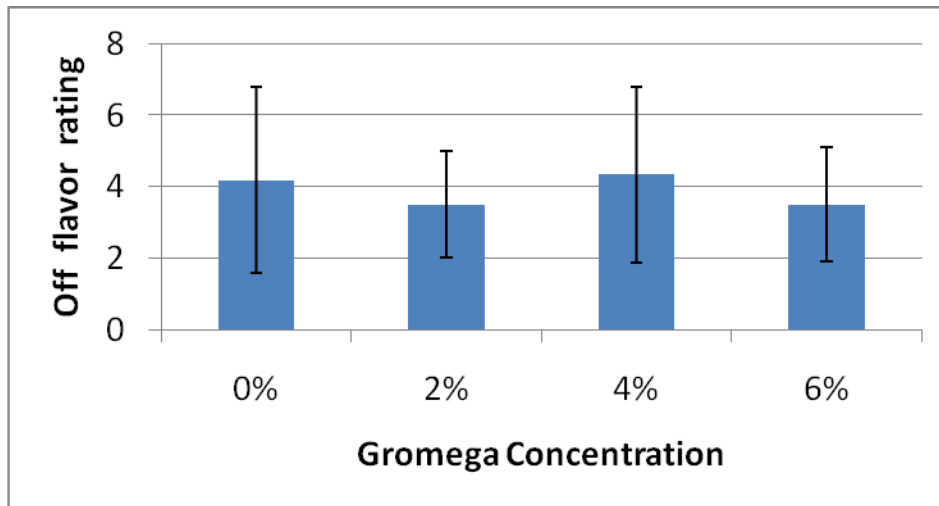


Figure twenty one – intensity of the detected off-flavor

If the Participant was able to detect an off flavor they were asked to describe the off flavor. Their responses are listed in appendix two.

Frankfurters

Fifty adults participated in the sensory analysis of the frankfurter products. Twenty four of the participants were male and twenty six were female. The age distribution is provided in table five.

| Age (years) | 18-24 | 25-34 | 35-44 | 45-54 | 55-64 | >65 |
|-------------|-------|-------|-------|-------|-------|-----|
| n | 12 | 9 | 4 | 13 | 11 | 1 |

Table five – the age distribution of the participants

The frequency of pork product consumption of the study population is provided in table six.

| Frequency | >1/week | 1 per week | one every other week | once per month | < once month |
|-----------|---------|------------|----------------------|----------------|--------------|
| n | 4 | 12 | 11 | 16 | 7 |

Table six – the frequency of pork product consumption of the study population

The study population were asked to rate their overall rating of the frankfurter products (figure twenty two). There was no significant difference in the participants hedonic rating of the different products ($F(3,49) = 0.9$ $p=0.4$).

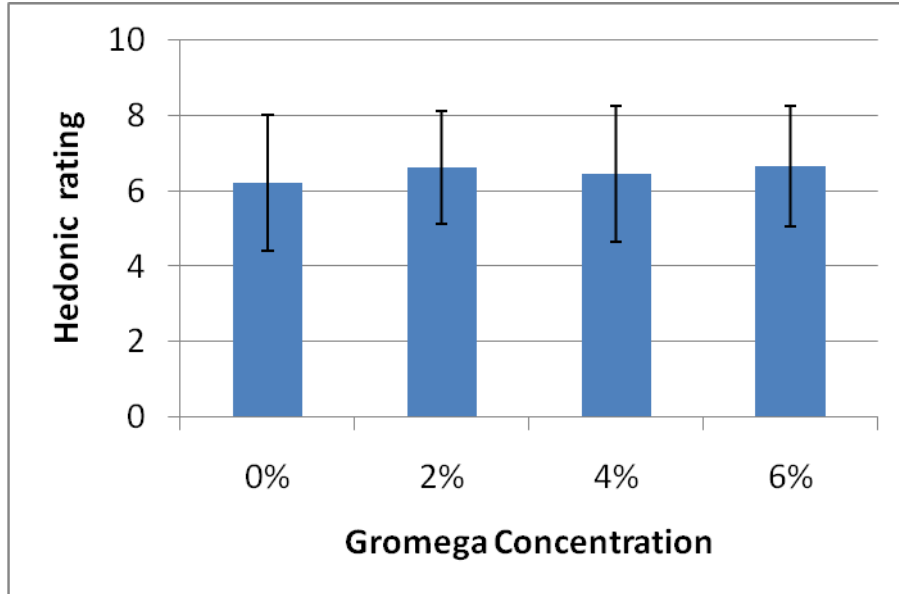


Figure twenty two – hedonic rating of the frankfurter products

The participants were asked to rate the juiciness of the frankfurter products (figure twenty three). There were statistically significant difference in the participants rated juiciness of the pork frankfurters ($F(3,49) = 8.54$; $p<0.05$). Post hoc analysis revealed that the 6% samples were rated as juicier than the 2% and 0% samples. The 4% and 2% samples were more juicy than the 0% samples.

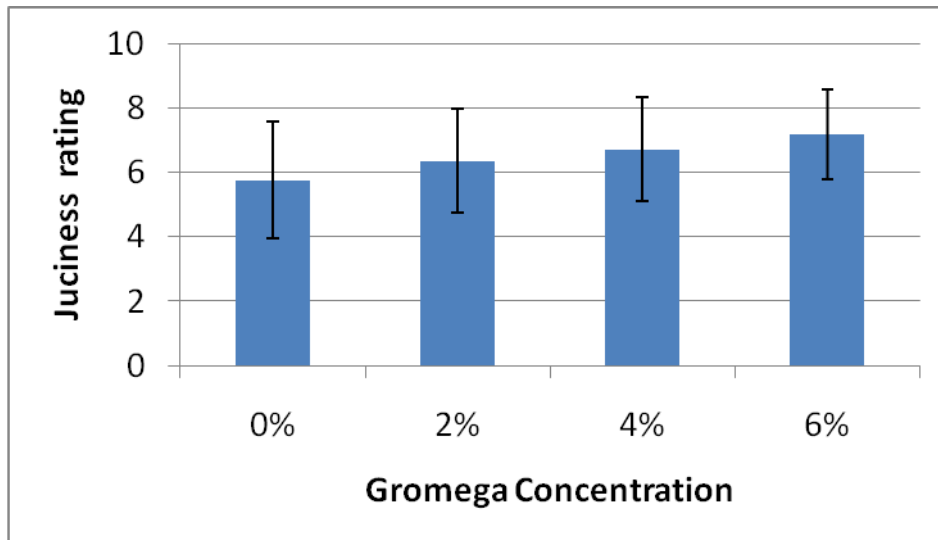


Figure twenty three – juiciness rating of the frankfurter products

The participants were asked to rate the texture of the frankfurter products (figure twenty four). There were statistically significant differences in the rated texture of the pork frankfurters samples ($F(3,49) = 4.49$; $p<0.05$). Post hoc analysis revealed that the texture rating of the 0% frankfurters was lower than for the 2%, 4% or 6% frankfurters.

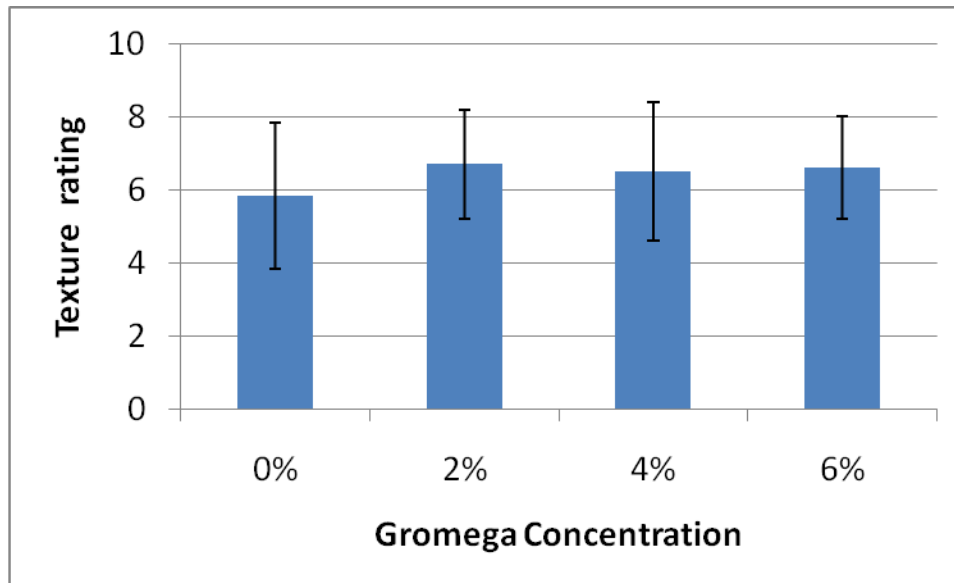


Figure twenty four – texture rating of the frankfurters

The participants were asked to rate the pork flavor of the four pork frankfurter products (figure twenty five). There were no statistically significant differences in the rated frankfurter flavor of the four frankfurter product samples ($F(3,49) = 0.25$; $p=0.86$).

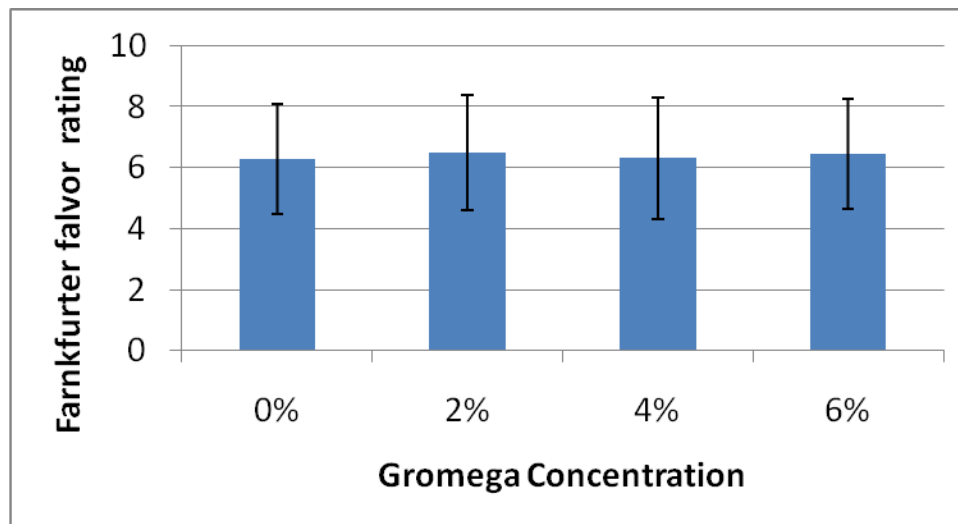


Figure twenty five – flavor rating of the frankfurter products

Participants were asked if they could detect an off flavor in the pork product they tasted (table seven). There were no statistically significant differences between the products in terms of detected off flavors ($p>0.05$)

| Sample | 0% | 2% | 4% | 6% |
|-------------------------------|----|----|----|----|
| % detect off flavor | 10 | 22 | 26 | 28 |
| % could not detect off flavor | 90 | 78 | 74 | 72 |

Table seven - % of people that could detect on off-flavor in the frankfurter products

For individuals who detected an off flavor they were asked to rate the intensity of the off flavor (figure twenty six). There was a statistically significant difference in the rated intensity of the off flavors ($F(3,33) = 6.15; p < 0.05$). Post hoc analysis revealed that the rating of strength of off flavors were significantly lower for the 2% and 4% products than the 0% product ($p < 0.05$).

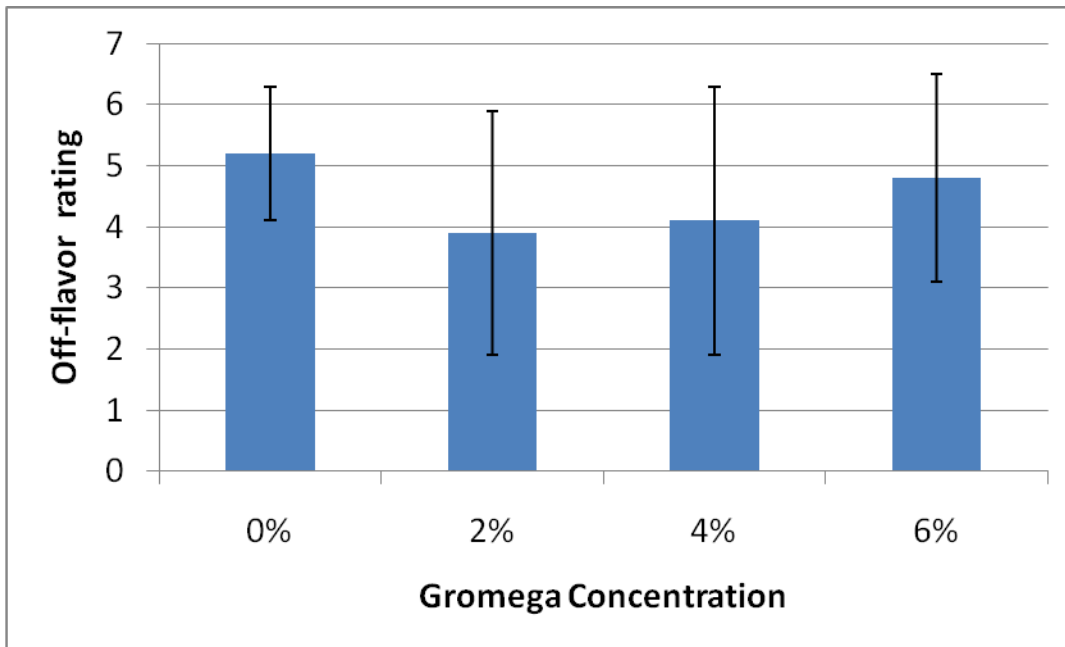


Figure twenty six – intensity of the off flavor detected in the frankfurter products

If the Participant was able to detect an off flavor they were asked to describe the off flavor. Their responses are listed in appendix three.

Bratwurst

Fifty adults participated in the sensory analysis of the loin products. Twenty four of the participants were male and twenty six were female. The age distribution is provided in table eight.

| Age (years) | 18-24 | 25-34 | 35-44 | 45-54 | 55-64 | >65 |
|-------------|-------|-------|-------|-------|-------|-----|
| n | 10 | 8 | 3 | 17 | 11 | 1 |

Table eight – the age distribution of the participants

The frequency of pork product consumption of the study population is provided in table nine.

| Frequency | >1/week | 1 per week | one every other week | once per month | < once month |
|-----------|---------|------------|----------------------|----------------|--------------|
| n | 1 | 6 | 13 | 17 | 13 |

Table nine – the frequency of pork product consumption of the study population

The study population were asked to rate their overall rating of the pork bratwursts (figure twenty seven). There was no significant difference in the participants hedonic rating of the different pork products ($F(3,49) = 1.16; p=0.3$).

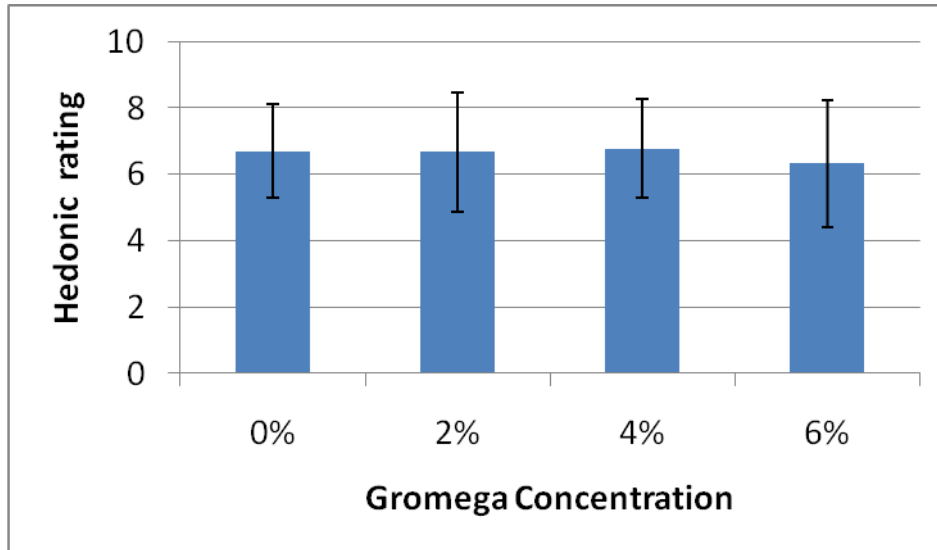


Figure twenty seven – hedonic rating of the bratwurst products

The participants were asked to rate the juiciness of the four bratwurst products (figure twenty eight). There was no significant difference in the participants rated juiciness of the pork loin ($F(3, 49)=2.69;p=0.06$).

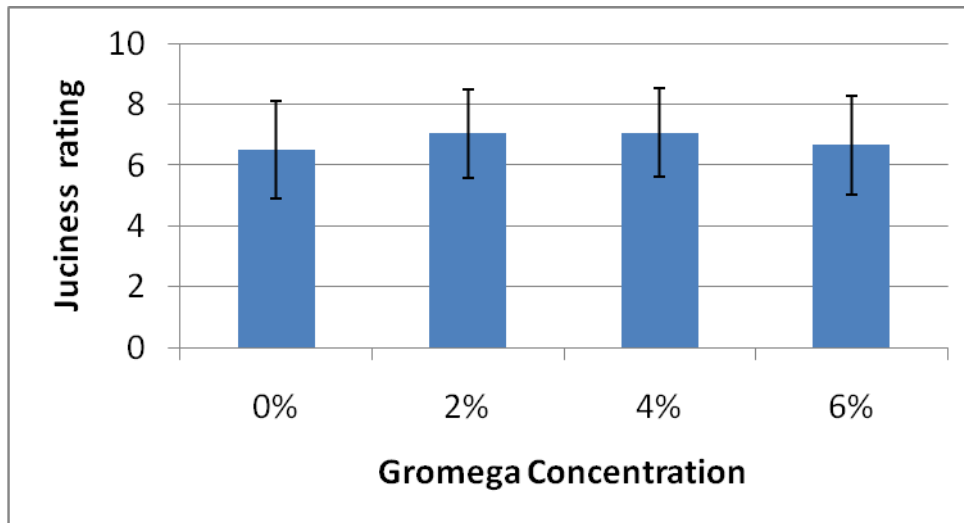


Figure twenty eight – juiciness rating of the bratwurst products

The participants were asked to rate the texture of the four bratwurst products (figure twenty nine). There were no statistically significant differences in the rated texture of the pork loin samples ($F(3,49) = 1.71; p=0.16$).

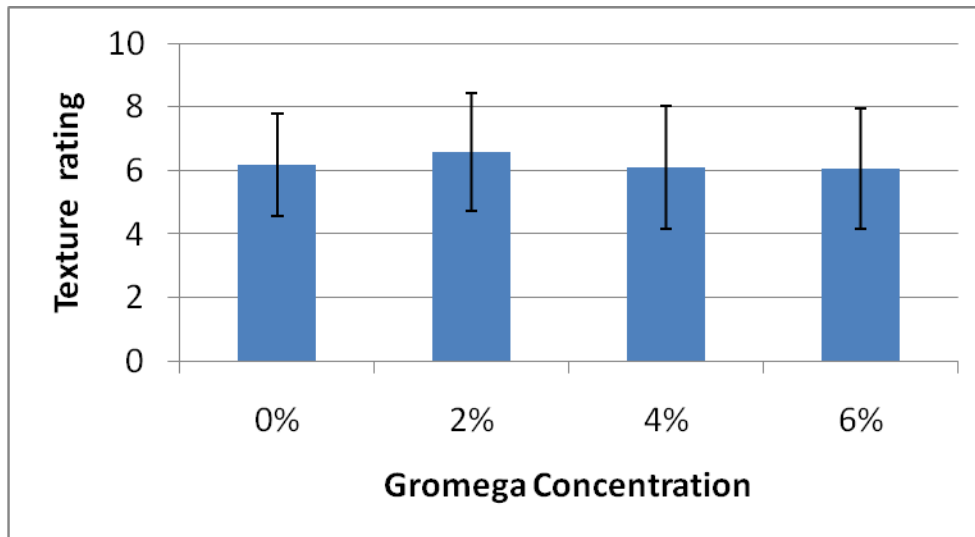


Figure twenty nine – texture rating of the bratwurst products

The participants were asked to rate the pork flavor of the four pork loin products (figure thirty). There were statistically significant differences in the rated pork flavor of the bratwurst samples ($F(3,49) = 5.3; p < 0.05$). Post hoc analysis revealed that the 6% bratwurst had a lower bratwurst flavor rating than 2% and 4% bratwurst samples ($p < 0.05$).

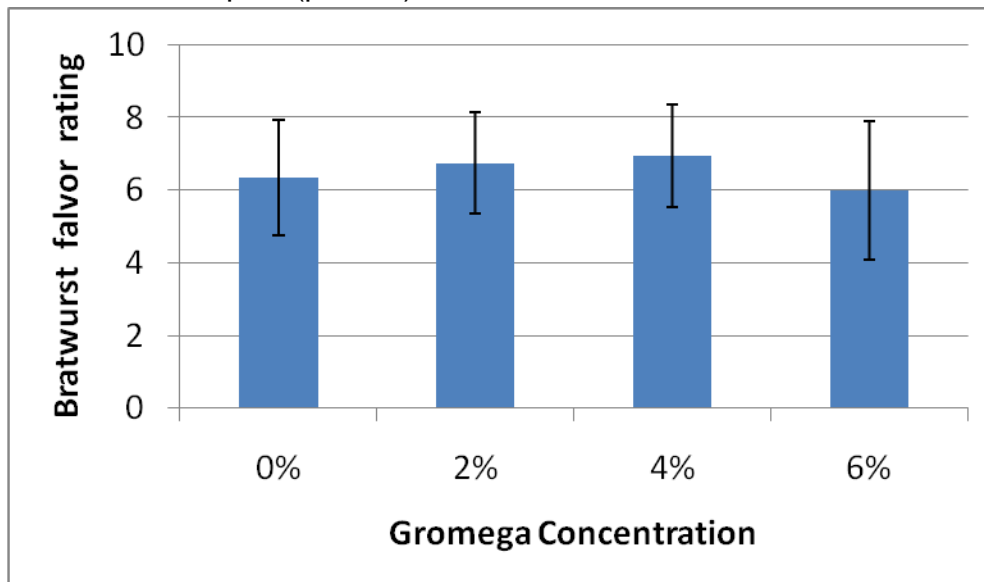


Figure thirty – flavor rating of the bratwurst products

Participants were asked if they could detect an off flavor in the pork product they tasted (table ten). There were no statistically significant differences between the products in terms of detected off flavors ($p > 0.05$)

| Sample | 0% | 2% | 4% | 6% |
|-------------------------------|----|----|----|----|
| % detect off flavor | 16 | 12 | 16 | 22 |
| % could not detect off flavor | 84 | 88 | 84 | 78 |

Table ten - % of participants who could detect an off-flavor in the bratwurst products

For individuals who detected an off flavor they were asked to rate the intensity of the off flavor (figure thirty one). There were no significant difference in the rated intensity of the off flavors ($F(3,33) = 1.08$; $p=0.37$).

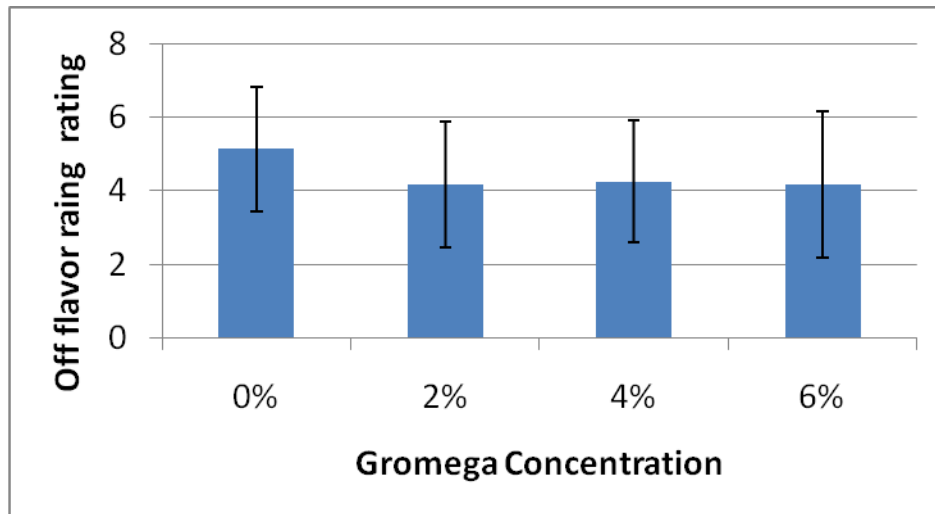


Figure thirty one – intensity of the off-flavor rating of the bratwurst products

If the Participant was able to detect an off flavor they were asked to describe the off flavor. Their responses are listed in appendix four.

Sausages

Fifty adults participated in the sensory analysis of the loin products. Twenty one of the participants were male and twenty nine were female. The age distribution is provided in table eleven.

| Age (years) | 18-24 | 25-34 | 35-44 | 45-54 | 55-64 | >65 |
|-------------|-------|-------|-------|-------|-------|-----|
| n | 13 | 7 | 5 | 10 | 14 | 1 |

Table eleven – the age distribution of the participants

| Frequency | >1/week | 1 per week | one every other week | once per month | < once month |
|-----------|---------|------------|----------------------|----------------|--------------|
| n | 1 | 8 | 15 | 12 | 14 |

The frequency of pork product consumption of the study population is provided in table twelve.

Table twelve – the frequency of pork product consumption of the study population

The study population were asked to rate their overall rating of the sausages (figure thirty two). There was no significant difference in the participants hedonic rating of the different pork products ($F(3,49) = 2.01$; $p=0.1$).

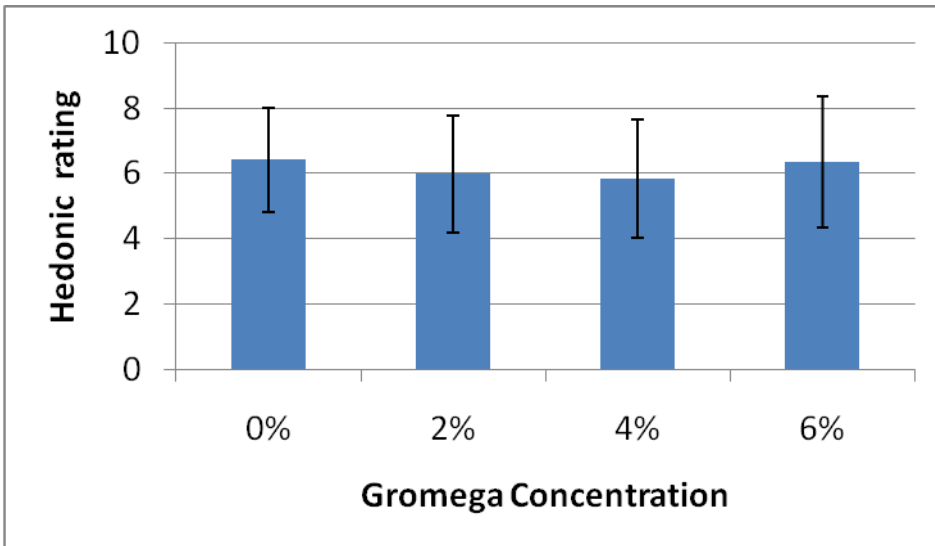


Figure thirty two – hedonic rating of the sausage products

The participants were asked to rate the juiciness of the four bratwurst products (figure thirty three). There was no significant difference in the participants rated juiciness of the pork loin ($F(3, 49)=0.73; p=0.73$).

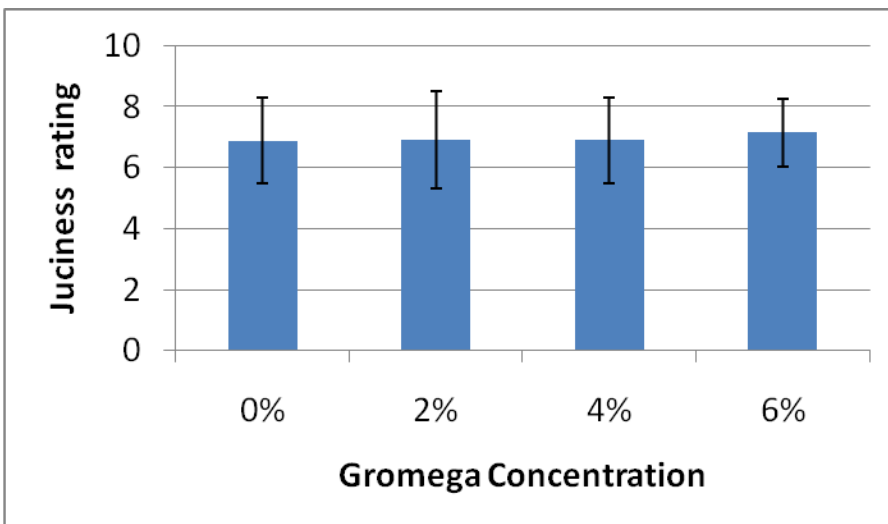


Figure thirty three – juiciness rating of the sausage products

The participants were asked to rate the texture of the four bratwurst products (figure thirty four). There were no statistically significant differences in the rated texture of the pork loin samples ($F(3,49) = 0.91; p=0.44$).

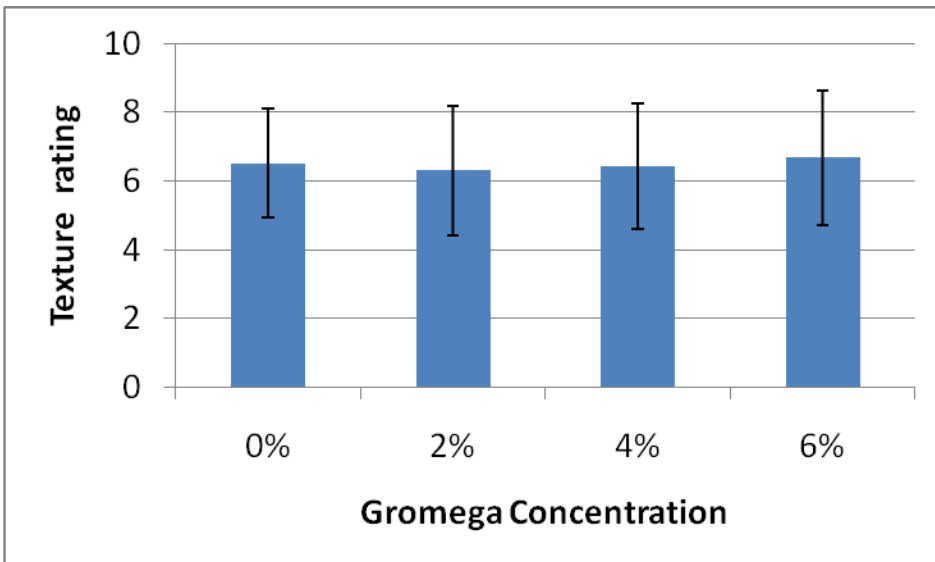


Figure thirty four – texture rating of the sausage products

The participants were asked to rate the pork flavor of the four pork loin products (figure thirty five). There were statistically significant differences in the rated pork flavor of the bratwurst samples ($F(3,49) = 1.7$; $p < 0.17$).

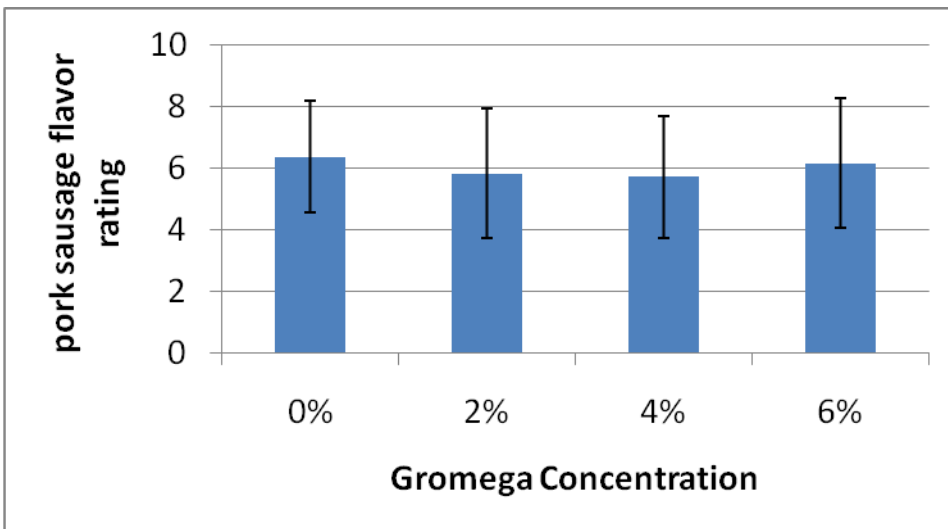


Figure thirty five – flavor rating of the sausage products

Participants were asked if they could detect an off flavor in the pork product they tasted (table thirteen). There were no statistically significant differences between the products in terms of detected off flavors ($p > 0.05$)

| Sample | 0% | 2% | 4% | 6% |
|-------------------------------|----|----|----|----|
| % detect off flavor | 26 | 14 | 24 | 24 |
| % could not detect off flavor | 74 | 86 | 76 | 76 |

Table thirteen – % of participants who could detect an off-flavor in the bratwurst products

For individuals who detected an off flavor they were asked to rate the intensity of the off flavor (figure thirty six). There were no significant difference in the rated intensity of the off flavors ($F(3,33) = 1.08$; $p=0.37$).

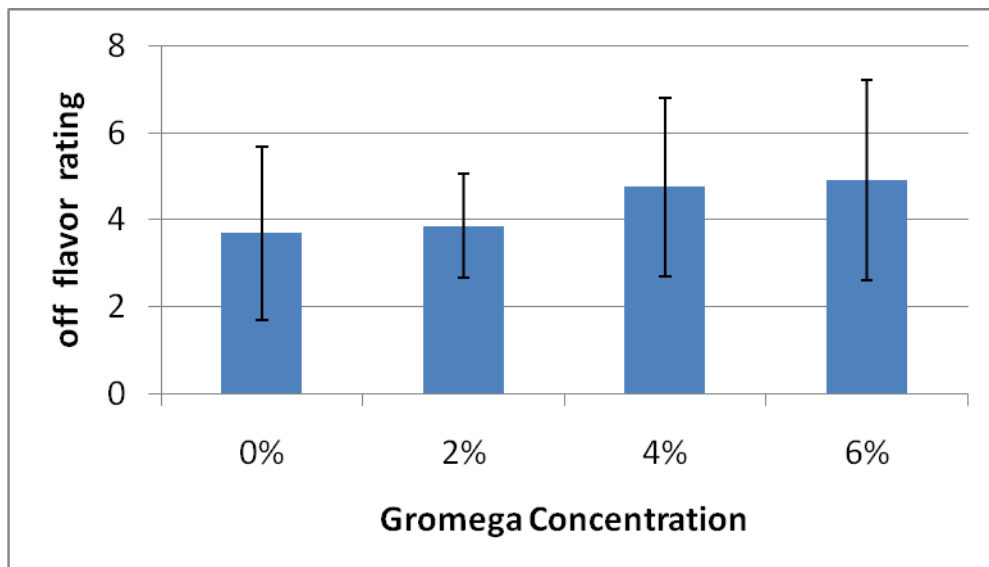


Figure thirty six – intensity of off-flavor rating of the sausage products

If the Participant was able to detect an off flavor they were asked to describe the off flavor. Their responses are listed in appendix five.

Discussion

This present study investigated the effect supplementing the diet of finisher pigs with 0%, 2%, 4% or 6% with an algal source of DHA/EPA on DHA/EPA content, TBARS value and consumer acceptability. It was found that increasing the amount of DHA/EPA in the finisher pig's diet increased tissue enrichment of DHA/EPA which resulted in the production of pork products that contained higher concentrations of DHA/EPA. While differences in TBARS value were found they were not consistent and generally lower than previous studies examining the effect of supplementing pig diets with omega-3 fatty acids. Moreover, there was no effect on consumer acceptability of the pork products.

While supplementing the diets of finisher pigs with DHA/EPA increases the amount of these nutrients found in pork products the diet would need to be supplemented with 6% DHA/EPA to provide sufficient amounts of DHA/EPA to provide health benefits. Current recommendations by the American Heart Association are to consume 0.5g of DHA/EPA each day and this amount was generally provided by products made from pigs feed a diet supplemented with 6% DHA/EPA. However, the 0.5g of DHA/EPA each day could come from a variety of sources including fish or omega-3 enriched milk or eggs. As many individuals avoid eating fish due to not liking it or concerns over environmental toxins the wider availability of omega-3 enriched products would provide

opportunities for individuals who do not consume fish a means to increase their daily intake of omega-3 fatty acids.

Gromega also provides alpha-tocopherol and it was anticipated that the levels of this essential nutrient would be higher in the enriched products. The amount of alpha-tocopherol was higher in the loins and bratwursts that were produced from pigs fed a diet containing 6% Gromega. However, there was no difference for the frankfurters and results were inconsistent for the sausage patties. It is important to note that the amount of alpha-tocopherol provided by these products is likely to only modestly contribute to daily vitamin E requirements.

Changes in TBARS values with time were largely small. These changes were not consistent and did not appear to effect consumer acceptance. In this study several efforts were made to reduce oxidation of the DHA and EPA. The products were vacuum packed and frozen shortly after manufacture which reduces the potential for oxidation. The sausage product also had the antioxidants BHA/BHT added. It is not clear from this study what the stability of shelf-life of fresh pork products that have been enriched with omega-3 fatty acids will be. Further research is warranted to determine this.

The consumer acceptability of the four products was good and the mean ratings of overall acceptance, tenderness, juiciness and flavor were not different between the control (0%) products and the products made from DHA/EPA pigs were not significant. These data indicate that pork products made from pigs whose diet was supplemented with 6% Gromega was acceptable. This is of interest as this level of supplementation was required to provide sufficient amounts of DHA/EPA in the pork products to potentially provide health benefits.

A potential barrier to the production of omega-3 enriched pork products is the increased cost of the feed formulations. However, the increased cost of feed to producers could be offset by two factors. First, this study the addition of LC n-3 FA to the feed reduced the feed conversion ratio. Moreover, pork products that are enriched with LC n-3 FA are likely to be premium products which will attract a premium price.

New dietary strategies are required to help reduce the burden of chronic disease on health care resources and expenditures. While many dietary strategies require large-scale changes to the diet they largely prove ineffective over the medium to long-term due to poor compliance. A different strategy is to reformulate commonly eaten products to make healthier options. The feasibility of this strategy has not been tested and research is warranted to determine the effectiveness of such a strategy.