Effect of introducing hemp oil into feed on the nutritional quality of pig meat

Jacques Mourot, Mathieu Guillevic

OCL 2015, 22(6) D610
© J. Mourot and A. de Tonnac, Published by EDP Sciences 2015
DOI: 10.1051/ocl/2015051

Available online at:
www.ocl-journal.org

Research Article – Dossier Open Access

Flax and hemp
Lin et chanvre

Dossier

The Bleu Blanc Cœur path: impacts on animal products and human health

Jacques Mourot and Auriane de Tonnac*

INRA, UMR 1348 PEGASE, 35590 Saint-Gilles, France

Received 3 July 2015 – Accepted 11 September 2015

Abstract – The first part of this article takes stock of the interest of incorporating extruded linseed into animal feed. The α-linolenic fatty acid and polyunsaturated fatty acid long chain n-3 derivative content of various animal products are explained and compared with products from animals receiving feed with no linseed. The second part of the article shows the interest of providing products for human consumption from the Bleu Blanc Cœur path. Clinical studies have been carried out. These products lower cholesterol, circulating triglycerides, weight and blood pressure. All in all, these products are of interest for human health.

Keywords: n-3 fatty acids / animal products quality / human health

Résumé – La filière Bleu Blanc Cœur : impacts en nutrition animale et humaine. La première partie de cet article dresse un bilan de l'intérêt de l'incorporation des graines de lin extrudées dans l'alimentation animale. Les teneurs en acides gras α-linolénique et en acides gras dérivés polyinsaturés à longue chaîne n-3 de divers produits animaux sont rapportés et comparés avec des produits issus d'animaux recevant une alimentation sans graines de lin. La seconde partie de l'article montre l'intérêt d'apporter à l'Homme les produits issus de la filière Bleu Blanc Cœur. Des études cliniques ont été réalisées. Ces produits permettent de baisser la cholestérolémie, les triglycérides circulants, le poids et la tension artérielle. Globalement, ces produits présentent un intérêt pour la santé de l'Homme.

Mots clés : Acides gras n-3 / qualité des produits animaux / santé de l'Homme

1 Introduction

Specialists in human nutrition have highlighted an imbalance in the consumption of lipids (ANC, 2001). A report has shown a deficiency in the consumption of n-3 fatty acids and excess consumption of n-6 fatty acids. During the past fifty years, the consumption of n-6 fatty acids multiplied by 2.6 compared to 0.6 for the n-3 (Ailhaud *et al.*, 2006). The change in the fatty acid composition of animal products is one of the reasons for the appearance of this food imbalance. The use of sunflower seed oil or maize as a salad oil instead of rapeseed or groundnut oil has also contributed to this imbalance.

The ratio of C18:2 n-6 fatty acids (linoleic acid, LA) to C18:3 n-3 (α linolenic acid, ALA) currently varies from 15 to 20 in the consumer's plate whereas the ANSES (*French Agency for Food, Environmental and Occupational Health & Safety*) recommends a ratio of 5. The guideline for the consumption of C18:3 n-3 is 2 g a day whereas current consumption is close to 0.8 g (Combe and Boué, 2001).

* Correspondence: jacques.mourot@rennes.inra.fr

An important source of α linoleic acid in human consumption is provided by animal products. They account for about 60% of daily intake (Combe and Boué, 2001).

There is a strong relationship between the fatty acids ingested by animals and those that will be deposited in the meat (Mourot, 2010). So the nutritional quality of the lipid fraction of meat, dairy and egg products can be modified. This characteristic has been successfully exploited for several years to provide fatty acids of interest for human health so that they can be found in the consumer's plate (Guillevic *et al.*, 2009). This livestock farming strategy enables the dietary deficiency of ALA in human food to be reduced. It is also of interest not only for human health (Legrand *et al.*, 2010) but for animal health too.

So an attempt must be made to make up for this deficit by using animal products from production sectors that incorporate more n-3 fatty acids into animal feed.

One of the most effective sources is linseed (Mourot, 2010). But the linseed used has to be selected for its n-3 fatty acid content. Depending on the seed varieties, there can be a difference in content varying from 1 to 25.

So, given that there is a very good correlation (close to 0.9) between n-3 food intake and its deposition in the products of monogastric animals, linseed that is low in n-3 will not be effective. Effective deposition is also increased when the linseed is extruded compared to an untreated seed or to linseed oil. (Vorin *et al.*, 2003).

The aim of the Bleu Blanc Cœur sector is to provide products with a better ratio between n-6 fatty acids and n-3 fatty acids. The main source of n-3 fatty acids is linseed for monogastric animals (and for humans), and grass for ruminants. The linseed is extruded to improve digestibility and feed efficiency and also to destroy antinutrients. Sources other than linseed can be used, depending on species, such as oilseed rape, alfalfa or hemp. An objective of results is expected for these Bleu Blanc Cœur animal products with a reduction in the n-6/n-3 ratio compared to a standard product.

2 BBC animal products

All animal species are involved in this approach. The effects will be more marked in monogastric animals than in ruminants. In fact, with ruminants, about 80% of the n-3 fatty acids are transformed in the rumen and so will not be found in their initial form in the animal products (Chilliard *et al.*, 2008). The aim of this article is to compare the n-3 fatty acid contents of various animal products from the Bleu Blanc Cœur sector or from standard sectors. All these products come from the same farming system; only the feed will change between the sectors.

2.1 Effect on milk

The results obtained with extruded linseed show increases in the 18:3 n-3 of the mik of 0.3–09 g/ 100 g AG, quite comparable to the increases observed with oil or non-treated seed, but lower than those observed in cows grazing a good quality grass (Ferlay *et al.*, 2008). Whereas linseed oil supplementation increases the 18:3 n-3 content in the milk, it reduces or tends to diminish the EPA and DHA contents, confirming that the 18:3 n-3 is not elongated into EPA and DHA (Chilliard *et al.*, 2008).

Figure 1 shows the evolution of the C18:3 n-3 percentage in the milk of animals not receiving extruded linseed at the start of the study and then receiving it for 9 weeks. The total lipid content does not vary during this period whereas the percentage of C18:3 n-3 is doubled after 9 weeks of feed with extruded linseed.

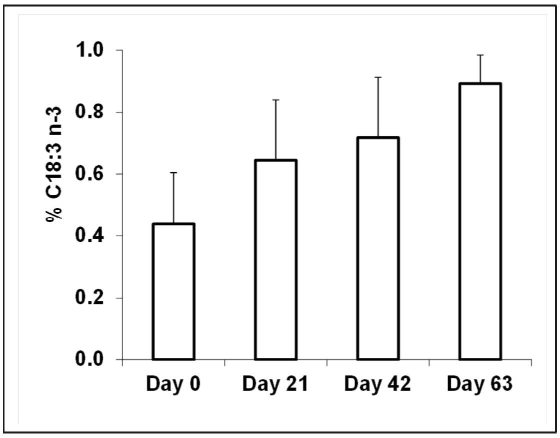

Fig. 1. Evolution of the percentage of C18:3 n-3 in the milk of cows receiving extruded linseed during lactation (laboratory data, study focused on 12 dairy farms).

2.2 Effect on meat

For beef, the impact of adding lipid supplements using linseed varies according to the nature of the basic diet (Bauchart *et a.*, 2005). Thus, extruded linseed supplementation has a positive effect that is more marked on the CLA and 18:1 11 *trans* contents of the meat when it is added to a straw-concentrate diet (30/70) than when it is added to a diet of maize-concentrate silage (60/40), but both diets lead to comparable effects on the 18:3 n-3.

The introduction of linseed has a strong impact on the meat of monogastric animals. The amounts of extruded linseed are 3 to 5% of the animal feed according to the species. Depending on the anatomical location, and in the context of a nutritional input that conforms to BBC specifications, the C18:3 n-3 content is multiplied by 2 to 4 compared to a standard production. For poultry, it is mainly chickens carrying labels that are concerned by the BBC sector. A standard chicken from the BBC sector would be of interest for human health, but this production would have difficulty in reaching economic profitability. For pork, every livestock system can be concerned (Corino *et al.*, 2014). In 2014, 1 350 000 pigs were marketed with the BBC label, i.e. about 6% of French production. The consumption of rabbit meat is marginal in France with about 2 kg/ person/ year, but the image of a meat that is nutritionally good in the mind of the consumer is reinforced by this omega 3 input. So BBC rabbit meat production is developing. The n-3 fatty acid content of these meats from monogastric animals are shown in Table 2. It is obvious that cuts with more fat will have the most n-3 precursor.

The LA/ALA ratio is lower than 5 for all the animals from the BBC sector. It is worth noting that rabbit meat with standard feed is also close to 5. This can be explained by the fact that rabbit meat is rich in n-3 fatty acids because of the incorporation of alfalfa into the standard feed.

With the linseed, the precursor is significantly increased ($p < 0.001$) in the meat, but the PUFA-LC n-3 are not significantly increased. This is the consequence of competition between the desaturases $\Delta 5$ and $\Delta 6$ for the desaturation of the n-6 and n-3 fatty acids. The transformation is estimated at between 1 and 5% of the ALA precursor (Alessandri *et al.*, 2009). The saturated fatty acid content is also reduced with the diets providing linseed, which is interesting for human health.

Meats were processed into cooked meat products or cooked dishes. The different processing procedures do not affect the n-3 fatty acids which remain in this form in products intended for human consumption.

Table 3 shows the C18 :3 content of different cooked meat products made from BBC pig meat. This content is compared

Table 1. Comparison of the percentages of different n-3 fatty acids in the *longissimus dorsi* muscle according to the breed and the diet.

Animal	Treatment	ALA	EPA	DPA	DHA
Cull cow Normandes (1)	Corn silage	0.37	0.12	0.44	0.04
	Corn silage + extruded linseed	1.24	0.32	0.50	0.04
Heifer Blond d'Aquitaine (1)	Concentrated	0.59	0.34	0.70	0.05
	Concentrated + extruded linseed	2.87	0.53	0.87	0.04
Steer Angus (2)	Pasture	0.69	0.20	0.45	0.02
	Pasture + milled linseed	1.23	0.28	0.55	0.02
Bull calf Bleu Belge (3)	Concentrated	1.27	0.39	0.88	0.09
	Concentrated + extruded linseed	2.01	0.46	0.97	0.08

From (1) Bauchart *et al.*, 2010 ; (2) Kronberg *et al.*, 2011 ; (3) Raes *et al.*, 2003.

Table 2. Fatty acid content (mg/100 g of product) in different cuts of meat and eggs according to diets.

Products	Diet	SFA(a)	ALA	EPA	DPA	DHA	LA/ALA
Chicken fillet (1)	standard	313	9	1	6	5	20.06
	BBC	270	34	4	12	8	4.45
Chicken leg (1)	standard	2731	109	1	10	7	15.03
	BBC	1981	405	9	27	10	3.32
Rabbit saddle (2)	standard	3718	394	3	10	2	5.27
	BBC	3493	1017	3	20	2	2.01
Rabbit leg (2)	standard	1433	148	4	14	3	5.63
	BBC	1080	295	5	22	3	2.22
Pork chop (3)	standard	3181	285	41	59	77	9.74
	BBC	2971	558	60	75	86	2.06
Eggs (1)	Standard	2079	34	1.3	7.3	51	8.83
	BBC	1606	330	9.0	13.2	79	1.69

(a) SFA: saturated fatty acids. (1) Laboratory data ; (2) Benatmane *et al.*, 2011 ; (3) Guillevic *et al.*, 2009.

Table 3. C18:3 n-3 content of different cooked meat products from the BBC path (mg ALA/100 g products).

Products	ALA, mg/100g	ANC, %
Country pâté	1487	74
Knack sausage	1371	68
Dried cured sausage	1322	66
Liver mousse	1146	57
Sausage	935	46
Smoked streaky bacon	935	46
Dried garlic sausage	780	39
Raw ham	543	27
Chitterling sausage	274	13
Roast pork	260	13
Cooked ham	99	5

From Guillevic *et al.*, 2009 and laboratory data.

to the Apports Nutritionnels Conseillés (ANC) (*Population Reference Intakes*) in ALA which is 2 g/day.

It is quite clear that some products with a high fat content must not be consumed in 100 g portions. For example, for the country pâté, the recommended amount is 40 g, once a week. In this case, for a BBC pâté, the input would be close to 600 mg, *i.e.* about 30% of the ANC, whilst for a standard product, the input would be close to 100 mg. The impact of the product from the BBC sector is therefore important.

2.3 Effect on eggs

The feed of layer hens has a strong influence on the lipid quality of the egg (Van Elswyk, 1997).

The effect is very marked for the input of the C18:3 n-3 precursor. As for the meats, the saturated fatty acid content is reduced when linseed is incorporated into the diet.

The egg is also an interesting source of DHA. This fatty acid increases in relation to the addition of the precursor to the diet, which makes it exceptional among animal products.

The average weight of commercial eggs is about 60 to 65 g. The additional input of ALA with BBC eggs will be about 180 to 200 mg per egg. Given that an individual will eat about 250 eggs a year, the consumption of BBC eggs spread over a year would enable about 7% more of daily needs to be covered compared to a standard egg.

For DHA and EPA, eating a BBC egg would cover more than 10% of daily requirements and the consumption of saturated acids would be reduced by about 300 mg.

2.4 BBC animal products and sensory analysis

Sensory analyses on various meats or processed products from the BBC sector were carried out to ensure that the significant presence of n-3 fatty acids did not adversely affect the smell or flavor of the food. These analyses were carried out at the sensory analysis laboratory (UE Alternative Livestock

Table 4. Effect of diets on the n-3 fatty acid content in the cooked roast, in mg of FA for 100 g of meat.

Diets	Coconut oil	Sunflower oil	Rapeseed oil	Extruded linseed	RSD	Diet effect
Lipid content %	2.6	3.3	2.8	2.9	0.9	NS
Σ FA n-3	24.4[a]	23.2[a]	27.2[a]	63.0[b]	5.4	$P < 0.001$
C18:3 n-3 ALA	6.4[a]	7.5[a]	8.7[a]	31.7[b]	5.2	$P < 0.001$
C20:5 n-3 EPA	2.1[a]	1.5[a]	2.5[a]	8.7[b]	0.8	$P < 0.001$
C22:5 n-3 DPA	7.6[a]	7.9[a]	9.1[a]	15.1[b]	2.0	$P < 0.001$
C22:6 n-3 DHA	2.4[ab]	2.1[ab]	1.9[a]	2.9[b]	0.5	$P < 0.02$
n6/n3	10.4[a]	11.8[a]	8.8[ac]	4.0[b]	1.4	$P < 0.001$

$n = 6$ pigs per batch, only castrated male pigs. The on-line values allocated the same letter are not significantly different at the 5% threshold.

Table 5. Pig meat: values of the different criteria analyzed.

Treatment	Tenderness	Juicy	Stringy	Global flavour	Pork flavour
Coconut	4.33 ± 1.35	3.30 ± 1.23	3.70 ± 1.77	4.78 ± 1.73	4.64 ± 1.57
Sunflower	4.35 ± 1.27	3.17 ± 1.31	3.59 ± 1.78	4.60 ± 1.54	4.37 ± 1.73
Rapeseed	4.09 ± 1.28	3.17 ± 1.37	3.81 ± 1.90	4.94 ± 1.38	4.83 ± 1.42
Extruded linseed	4.59 ± 1.29	3.59 ± 1.61	3.80 ± 1.74	4.98 ± 1.34	4.70 ± 1.63

No significant effect was observed.

Farming and Health of Monogastrics, INRA, Le Magneraud, Karine Méteau).

A study carried out on pig meat showed that there was no deterioration in the organoleptic qualities of the roast. Table 4 shows the n-3 fatty acid content of the cooked roasts distributed to the judging panel trained in sensory analysis, and Table 5 shows the values of the analyzed criteria. Similar results were obtained for the side of pork for the same study.

The comments collected during the 12 sessions showed a more compact meat for the animals that received feed containing copra oil and a better satisfaction index for the meat of animals from the linseed sector.

Other sensory analyses carried out on rabbit meat (Meteau *et al.*, 2011) and dry cured hams (Mourot *et al.*, 2012) showed that products from the BBC sector are identical to standard products or were better appreciated.

3 Interest for human health of products from the BBC path

The BBC approach is not limited to a report showing an increase in the ALA content of food. BBC also sought to show the interest for human health of consuming these products. Various studies were set up by BBC in collaboration with the CERN (Centre for the Study and Research of Human Nutrition, hospital of Lorient) and research bodies. Two studies in particular will soon be reported.

One relates to the effect of a foodstuff enriched in ALA on human blood parameters. This product is bread enriched with ALA via the incorporation of extruded linseed during its production.

The other study relates to the effect of a BBC menu compared to a standard menu. In both cases, the foodstuffs are identical, but for one they come from the BBC sector and the other from a standard sector.

The incorporation of linseed while bread is being made is an ancestral practice which was already applied among Romans who called it "Greek" bread.

In this study (Weill *et al.*, 2002), 5% of extruded linseed is introduced instead of 5% of flour to make experimental bread. For a period of 28 days, thirty-two healthy volunteers substituted this experimental bread for their usual bread, without any other modification to their diet. The average consumption per volunteer was 80 g of bread, *i.e.* 4 g of extruded linseed, providing an additional 0.8 g of ALA. Each volunteer was his own witness. Circulating fatty acids were measured at the beginning and end of the experimental period. When this period ended, an enrichment of the total n-3 AG serum was observed (3.22% of the total fatty acids at day 0 *vs.* 3.78 at day 28 *i.e.* +17%, $p < 0.05$). For ALA (0.63% *vs.* 0.82) and EPA (0.69% *vs.* 0.90) the increase is proportionately equivalent (+30%; $p < 0.01$). The n-6/n-3 ratio in the serum decreases by 14% (12.5 *vs.* 11.1). A reduction in total triglycerides is also observed (1.1 g/l *vs.* 0.72: −35%; $p < 0.05$) as well as in total cholesterol (2.12 g/l *vs.* 1.96: −8%; $p < 0.01$).

The effects observed could be due on the one hand to the cooking process, which would improve the metabolic use of the fat content of ALA-rich linseed, and on the other hand to the non-fatty components of the seed (mucilage, lignan). Enriching everyday food with small quantities of linseed thus seems an interesting way of achieving the ANC guidelines.

One of the other studies carried out in humans related not to a product but to a menu distributed for several weeks (Legrand *et al.*, 2010). A study compared the effect of two diets, on the weight and lipid parameters of obese volunteers (IMC: 31.4 ± 3.8). One diet was a control diet (RT) and the other (Rn3) was the same products as with RT but all from the BBC sector. The 160 volunteers were divided into two groups and they received the diets (2000 kcal/day) for a period of 90 days. The control diet was representative of contemporary food (composed according to INCA 2 data) with 60% of lipids of plant origin, a low AGS rate (24.3%), a high AGPI/AGS ratio (0.7) and a high n-6/n-3 ratio with a value of 18. The experimental diet (Rn3) composed of Bleu-Blanc-Cœur products provided 78% of lipids of animal origin, a high AGS rate (30.9%), a low AGPI/AGS ratio of 0.29, and a low n-6/n-3 ratio at 5.

The ALA content was on average 0.85 g per day for RT and 2 g for Rn3 including 1.75 provided by BBC products and 0.25 g by a complement in the form of extruded linseed flour.

The subjects were their own witness. After 90 days, the % of C18:2 n-6 (LA) of the erythrocytes increased in the volunteers of batch RT (20.9 ± 4.0 to 24.0 ± 5.5, $p < 0.001$) whereas for Rn3 it did not vary. The percentage of ALA did not vary for batch RT whereas it increased significantly for batch Rn3 (0.4 ± 0.1 to 0.7 ± 0.4, $p < 0.001$). EPA (0.6 ± 0.2 to 0.4 ± 0.2, $p < 0.001$) and DHA (2.6 ± 0.8 to 2.3 ± 0.8, $p < 0.05$) decreased in batch RT. In batch Rn3, EPA and DHA increased but not significantly (EPA 0.73 ± 0.3 to 0.77 ± 0.3 NS; DHA 2.6 ± 0.8 to 2.7 ± 0.9 NS).

The other lipid parameters did not differ significantly between the volunteers from the 2 batches even though they showed a reduction in triglycerides and LDL-cholesterol and an increase in HDL-cholesterol.

All the volunteers lost weight, approximately 3 kg, but this is certainly due to a balanced normocaloric diet, which was not how they ate before this study began. Some volunteers from the two groups agreed to return for a new assessment 150 days after the end of the study. Those in group RT had put on an average of 2.7 kg whereas those from the Rn3 group had continued to lose weight (+0.2 kg). Thus, the obese subjects receiving a diet enriched in n-3 fatty acids did not put on weight again after returning to a free diet, unlike the obese subjects subjected initially to a standard type of diet.

Other work was carried out on humans, in particular studying the effect of the distribution of dairy products from BBC production. The ALA rate was increased in these products as well as that of *trans* fatty acids, in particular the CLA 9-cis 11-trans (Schmitt *et al.*, 2006). After ingestion of these products, an increase in the circulating ALA rate after 30 days of distribution was observed. The blood insulin level on an empty stomach was lower ($p < 0.05$) and insulin resistance decreased too but not significantly. The lipid parameters were not significantly affected.

The interest for human health of α linolenic acid and n-3 long chain derivatives has been demonstrated by many studies. By this work with humans, the BBC sector confirmed all the interest of regularly consuming products that are naturally enriched in n-3 fatty acids.

4 Conclusion

Extruded linseed added to animal feed has a strong impact on the C18:3 n-3 content. On the other hand, the PUFA-LC n-3 derivatives do not vary very much in relation to ALA in the diet. BBC sector products are able to respond to the aims of the ANSES (*French Agency for Food, Environmental and Occupational Health and Safety*) who recommend that all food vectors enabling the ALA input in the human diet to be increased should be taken into consideration. What is more, the saturated fatty acid content reduces, which has a positive impact on human health. The interest of these products for human health has been confirmed by studies on humans. So they must be given a more prominent position in our food and remain economically accessible to everyone.

The strong link which exists between animal nutrition and the consequences for human nutrition must be looked into more thoroughly and stressed by the media and the medical world. The development of agriculture with a health vocation to preserve human health has to be encouraged.

Acknowledgements. The authors declare having no conflict of interest.

References

Ailhaud G, Massiera F, Weill P, Legrand P, Alessandri JM, Guesnet P. 2006. Temporal changes in dietary fats: role of n-6 polyunsaturated fatty acids in excessive adipose tissue development and relationship to obesity. *Progr. Lipid Res.*, 45: 203–236.

Alessandri JM, Extier A, Astorg P, Lavialle M, Simon N, Guesnet P. 2009. Gender-related differences in omega-3 metabolism. *Nutr. Clin. Metabol.* 23: 55–66.

ANC, Apports Nutritionnels Conseillés pour la population française, 2001 AFSSA. Paris: Ed. Tec & Doc.

Bauchart D, Gladine C, Gruffat D, Leloutre L, Durand D. Effects of diets supplemented with oil seeds and vitamin E on specific fatty acids of Rectus abdominis muscle in charolais fattening bulls. In: ndicators of milk and beef quality, EAAP. Wageningen: Academic Publishers ed., 2005, Vol. 112, pp. 431–436.

Bauchart D, Thomas A. 2010. Breeding factors and health value of meat fatty acids. In: Muscle et Viande de Ruminants. Paris: Quae Ed., pp. 131–142.

Benatmane F, Kouba M, Youyou A, Mourot J. 2011. Effect of a linseed diet on lipogenesis, fatty acid composition and stearoyl-CoA-desaturase in rabbits. *Animal* 5: 1993–2000.

Chilliard Y, Bauchart D, Lessire M, Schmidely P, Mourot J. 2008 Qualité des produits : modulation par l'alimentation des animaux de la composition en acides gras du lait et de la viande, *INRA Prod. Anim.* 21: 95–106

Combe N, Boué C. 2001. Apports alimentaires en acides linoléique et α-linolénique d'une population d'Aquitaine. *OCL* 8: 118–121.

Corino C, Rossi R, Cannata S. 2014. Effect of dietary linseed on the nutritional value and quality of pork and pork products: Systematic review and meta-analysis. *Meat Sci.* 98: 679–688.

Ferlay A, Agabriel C, Sibra C, Journal C, Martin B, Chilliard Y. 2008. Tanker milk variability of fatty acids according to farm feeding and husbandry practices in French semi-mountain area. *Dairy Sci. Technol.* 88: 445–454

Guillevic M, Kouba M, Mourot J, 2009. Effect of a linseed diet on lipid composition, lipid peroxidation and consumers evaluation of fresh meat and French cooked pork meats. *Meat Sci.* 81: 612–618.

Kronberg SL, Scholljegerdes EJ, Lepper AN, Berg EP. 2011. The effect of flaxseed supplementation on growth, carcass characteristics, fatty acid profile, retail shelf life, and sensory characteristics of beef from steers finished on grasslands of the northern Great Plains. *J. Anim. Sci.* 89: 2892–2903.

Legrand P, Schmitt B, Mourot J, *et al.* 2010. The consumption of food products from linseed-fed animals maintains erythrocyte omega-3 fatty acids in obese Humans. *Lipids*, 45: 11–19.

Meteau K, Juin H, Mourot J, *et al.* 2011. Effet de l'apport d'acides gras n-3 et d'antioxydants végétaux dans l'aliment sur les qualités sensorielles de la viande de lapin. *Journées de la Recherche Cunicole* 14: 97–100.

Mourot J. 2010. Que peut-on attendre des pratiques d'élevage pour la viande de porcs et autres monogastriques ? *OCL* 17: 37–42

Mourot J, Robert N, Raynaud L, Arturo-Schaan M, Roger L. 2012 Effet de l'apport d'acides gras n-3 et d'antioxydants végétaux dans l'alimentation du porc sur les qualités nutritionnelles et sensorielles du jambon sec. *Journées de la Recherche Porcine* 44, 51–52.

Raes K, De Smet S, Balcaen A, Clayeys E, Demeyer D. 2003. Effect of diets rich in n-3 polyunsatured fatty acids on muscle lipids and fatty acids in Belgian Blue double-muscled young bulls. *Reprod. Nutr. Dev.* 43, 331–345.

Schmitt B, Ferry C, Daniel N, Weill P, Kerhoas N, Legrand P, 2006. Effet d'un régime riche en acides gras n-3 et en CLA 9-cis, 11-trans sur l'insulinorésistance et les paramètres du diabète de type 2. *OCL* 13 : 70–75

Van Elswyk M.E. 1997. Comparison of n-3 fatty acid sources in laying hen rations for improvement of whole egg nutritional quality: a review. *Br. J. Nutr.* 78: 61–69.

Vorin V, Mourot J, Weill P, Robin G, Mounier A, Peiniau P. 2003. Effet de l'apport d'acides gras n-3 dans l'alimentation du porc sur les performances de croissance et la qualité de la viande. *Journées de la Recherche Porcine* 35, 251–257.

Weill P, Schmitt B, Chesneau G, Daniel N, Legrand P. 2002. Introduction de graines de lin cuites dans du pain. Effets sur les paramètres lipidiques sanguins de consommateurs réguliers de pain. *Nutr. Clin. Métabol.* 16: 16.

Cite this article as: Jacques Mourot, Auriane de Tonnac. The Bleu Blanc Cœur path: impacts on animal products and human health. OCL 2015, 22(6) D610.