DN Forum
Dairy Nutrition Forum
A PUBLICATION FOR INDUSTRY AND HEALTH PROFESSIONALS
Volume 11 Issue 2 2019

THIS ISSUE PAGES

National Dairy Council | fhi FOOD FOR HEALTH IRELAND

Nutritional attributes of grass-fed dairy

EDITORIAL

Consumers are becoming increasingly conscious around aspects such as food origin and sustainable food systems. With one of the lowest carbon footprints internationally, Irish dairy production is considered to be highly efficient. As it is a predominantly grass-fed system, it converts human-inedible material, such as grass, into a nutrient-dense, protein-rich, affordable food. In this edition, we explore the nutritional attributes of grass-fed dairy and explore whether this locally-produced product has any additional benefits.

We hope you enjoy this edition of *DN Forum* and look forward to any feedback or comments you wish to share: nutrition@ndc.ie

Marianne Walsh
Dr Marianne Walsh
Nutrition Manager
The National Dairy Council (NDC)

Summary points

- Ireland has a grass-fed dairy system, with cows grazing outdoors for up to 300 days per year. As this grazing system is closer to a cow's natural environment, it is preferable from an animal-welfare perspective and research suggests that it results in a lower contribution to methane emissions.
- The nutritional composition of milk varies according to the cow's diet, with significantly higher fat and protein content found in grass-fed milk compared to the indoor-milk system (which gives greater volume yield). Grass-fed milk has been shown to have a significantly higher content of a variety of beneficial nutrients, including a two-fold increase in conjugated linoleic acid (CLA) and significantly higher concentrations of n-3 fatty acids. It has improved n-3 to n-6 ratio and significantly lower thrombogenicity index scores compared to that of indoor-fed milk.
- Grass-fed milk has significantly higher levels of the vitamin A precursor, ß-carotene and minerals, including calcium, phosphorus, magnesium and manganese. Higher levels of copper and selenium have been found in 'indoor-fed' milk. However, the magnitude of each of these differences does not appear to have a significant biological effect considering the consumption volume.
- While research demonstrates that pasture feeding has a beneficial effect on the nutritional profile of milk, clinical studies demonstrating subsequent effects on human health are lacking. However, given the positive image of grass-fed dairy, this attribute could be helpful in encouraging milk consumption, which would irrespectively contribute to overall nutrient intakes.

The nutritional attributes of grass-fed dairy

Dr Tom F. O'Callaghan
Research Officer, Teagasc Department of Food Chemistry and Technology, Moorepark, Co. Cork; and Principal Investigator with Food for Health Ireland (FHI).


Dr Tom F. O'Callaghan

Introduction

With the exception of brewing, dairy science is the oldest sector within food science and has been the subject of study for over 150 years. Much has been documented about its composition and its contribution to nutritional intake. Globally, milk produced by cows is the most commonly consumed by humans. It is primarily composed of water, protein, fat and lactose but also contains several hundred minor constituents including vitamins, minerals and flavour compounds[1]. These contribute to the unique nutritional and sensory properties of milk (**Figure 1**).

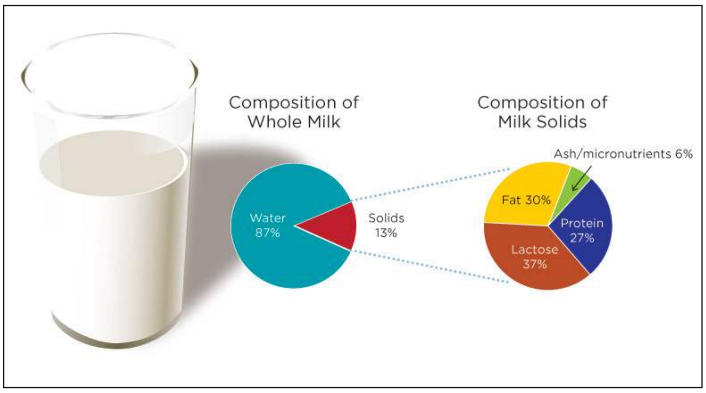

Figure 1: The composition of cow's milk

The composition of milk varies and is influenced by a variety of factors including cow breed, age, health, stage of lactation and diet. Among the macronutrients, a cow's diet most significantly affects the fat portion of milk, while changes in the milk-protein profile are primarily dictated by the animal's genetics. There are a variety of cow-feeding systems practiced all over the world, primarily driven by climate and environmental conditions, land availability and the energy requirements of the cow. Ireland's temperate climate, with plentiful rainfall and fertile soils, provides excellent conditions for the growth of grass, which serves as a cost-effective feed source, enabling the cow to graze outdoors for the majority of the year. A recent study has demonstrated that, on a fresh matter basis, forage accounts for approximately 96% of the Irish cow diet, equating to approximately 82% of total dry matter intake[2]. Pasture feeding is supplemented with small amounts of concentrates when there is reduced grass growth. Indoor feeding systems, referred to as 'total mixed ration' (TMR) feed, generally consist of silage, grain and added vitamins and minerals.

This pasture or 'grass-fed' dairy system provides Irish dairy purveyors with a unique selling point on the international market, resulting from consumer perceptions and associations with a 'healthier', more natural product and improved animal welfare compared to more conventional indoor, TMR feeding systems[3]. Pasture-based feeding also results in a lower contribution to methane emissions[4].

In some regions, dairy products from a grass-fed system command a premium price, due to consumer demands for a 'greener product', considered more nutritious, natural and sustainable. While these perceptions of a grass-fed system can conjure up the image of a superior product, grass-feeding does not unanimously guarantee higher quality milk. However, some of these perceptions have been substantiated by research with a variety of beneficial changes to the composition and quality of milk from grass-fed cows[5].

The objective of this article is to offer insight into the nutritional attributes of milk and the impact that grass-feeding has on the composition and quality of milk and dairy products.

Nutritional factors in milk composition

Cow's milk typically contains 3.4% protein, which is comprised of approximately 80% casein and 20% whey. These families of milk proteins possess an array of biological properties and whey protein is a rich source of both essential and branched chain amino acids (BCAAs)[6]. The role of the branched chain amino acids (valine, leucine and isoleucine) in tissue growth and repair has gained much interest as an important nutritional supplement for athletes and other cohorts of consumers. Milk proteins are also a source of a variety of bioactive peptides, which are released during gastrointestinal digestion by hydrolysis processes. These bioactive peptides are capable of exerting a variety of health benefits including anti-hypertensive, antioxidant and anti-inflammatory activities[7,8].

Unlike the protein fraction of milk, the fat component is significantly dependent on the animal's diet. There are seasonal and breed variations in the fat content of cow's milk, but it is typically standardised to contain 3.6% fat. This is comprised mainly of triglycerides (about 98%) with fatty acids of varying chain length and saturation. To date, approximately 400 different fatty acids have been identified in milk[9]. These fatty acids are primarily derived from two main sources: *de novo* fatty acid synthesis in the mammary gland (responsible for fatty acids C4:0 to C14:0) and long-chain fatty acids, which are derived from the animal's feed. Palmitic acid (C16:0) is the most abundant saturated fatty acid in cow's milk and is derived from both *de novo* synthesis and the diet[10].

Saturated-fatty acids account for more than half of the fatty acids in milk and can have a significant impact on the technological properties of high-fat dairy products such as butter[11]. There has been a negative perception of some dairy products in the past due to their saturated fat content, however, a variety of these saturated fatty acids have been reported to have positive effects. While lauric acid (C12:0), myristic acid (C14:0) and palmitic acid (C16:0) have been associated with hypercholesterolemia[12], butyric acid (C4:0) has been demonstrated to modulate gene function and may have an effect in cancer prevention[13,14]. Caprylic (C8:0) and capric acid (C10:0) may have antiviral activities and lauric acid (C12:0) has been hypothesised to have antiviral and antibacterial functions[15]. Furthermore, stearic acid (C18:0) appears to have a neutral effect on serum cholesterol levels[15]. Despite findings related to individual fatty acids, the food matrix also plays an important role in the overall health impact, rather than the individual nutrients and components of the food working in isolation[16].

Among the polyunsaturated fatty acids in milk, α-linolenic acid and linoleic acid are the predominant n-3 and n-6 long-chain essential fatty acids found in milk. Both n-3 and n-6 fatty acids are precursors to eicosanoids that have been associated with cardio protective effects[17]. While n-3-derived eicosanoids possess anti-inflammatory properties, n-6-derived eicosanoids possess pro-inflammatory properties[18]. The ideal ratio of these fatty acids in the diet is hypothesised to be 1:1-4 (n-3: n-6); however, due to changes in the western diet in recent decades this ratio is thought to be between 1:10 and 1:20[19]. Coinciding with this, a variety of chronic inflammatory diseases have been observed and associated with an unfavourable ratio[18]. Therefore, foods such as 'grass-fed' milk, with a beneficial n-3 to n-6 fatty acid ratio, may be preferable from a health perspective[20].

Conjugated linoleic acid (CLA) has been a topic of interest in recent years, associated with a variety of potential health benefits and biological functions. These include a reduction in body weight, cardiovascular disease risk, cancer risk and modulation of both immune and inflammatory responses[21]. The most commonly recommended intake of CLA is 0.8g/day, which is extrapolated from animal models and few human studies[22]. The estimated intake levels in Europe, the US and Canada are lower at 0.21g/day[22]. With this, dairy products, which are naturally rich in CLA, have been highlighted as an opportunity to increase human CLA consumption, bringing it closer to the recommended intake[23] and providing a functional benefit[24].

Novel Irish research and nutritional differences of 'grass-fed' dairy

It is estimated that approximately 10% of the global milk supply is derived from grass-fed dairy systems[25]. Given the importance of the grass-fed system to the sustainability, competitiveness and perception of Irish dairy, the *Profiling Milk from Grass* project was initiated by Teagasc in 2015. The goal of this project was to bring together a multidisciplinary team of scientists to comprehensively compare the impact of pasture versus indoor TMR diets on the composition, quality and sensory properties of milk and dairy products. The details of the herds and diets of the study are discussed in detail by O'Callaghan[26]. The results to date have highlighted that pasture feeding of cows has a significant effect on the composition and quality of milk[26,27], butter[11], cheese[28,29,30] and whole-milk powder[31].

The grass-fed milk system was demonstrated to have a significant effect on the macronutrient composition of milk, with significantly higher contents of fat and protein, while indoor TMR feeding resulted in increased milk yield by volume[27]. In addition, the fatty-acid profile of both milks were significantly different. Grass-fed milk had a significantly higher content of a variety of beneficial nutrients including a two-fold increase in CLA (specifically CLAc9t11, shown in **Figure 2**) and significantly higher concentrations of n-3 fatty acids (**Figure 3**). TMR-derived milks had significantly higher concentrations of the less-favourable n-6 (**Figure 4**) and palmitic (C16:0, **Figure 5**) fatty acids [27]. Cheddar cheese derived from grass-fed milk has been shown to have significantly higher content of vaccenic acid[28]. Vaccenic acid is bio-converted to CLA in humans and, therefore, can contribute significantly to the amount of CLA made available from dairy[32,33].

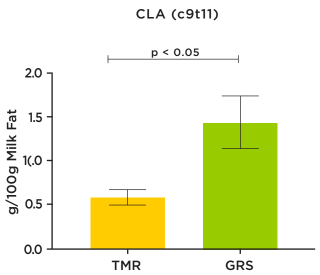

Figure 2: Impact of indoor (TMR) versus pasture (GRS) feeding on the conjugated linoleic acid (CLA c911) congtent of milk.

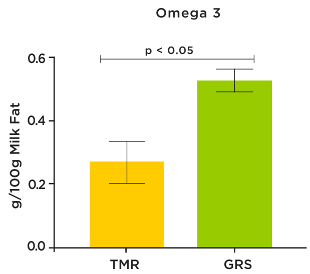

Figure 3: Impact of indoor (TMR) versus pasture (GRS) feeding on the Omega-3 fatty acid content of milk.

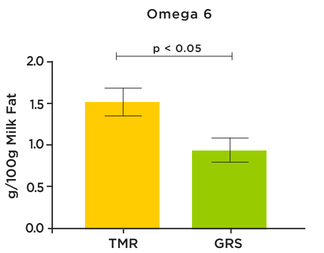

Figure 4: Impact of indoor (TMR) versus pasture (GRS) feeding on the Omega-6 fatty acid content of milk.

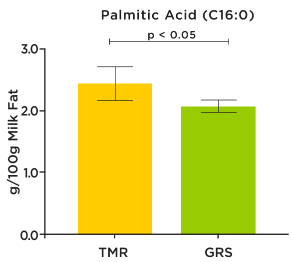

Figure 5: Impact of indoor (TMR) versus pasture (GRS) feeding on the palmitic acid content of milk.

As shown in **Figure 6**, grass-fed dairy products have also been demonstrated to have significantly higher levels of the vitamin A precursor, ß-carotene, which results in dairy products being more yellow in colour and giving Irish butter its characteristic 'golden' hue[11]. Grass-fed dairy products have significantly improved n-3 to n-6 ratio and significantly lower thrombogenicity index scores compared to that of TMR products[26,28]. Gulati *et al.*[30] also demonstrated a significant effect of pasture feeding on the mineral composition of milks, with grass-fed milks having significantly higher concentrations of calcium and other minerals (shown in **Table 1**).

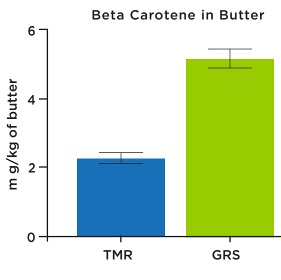

Figure 6: Impact of indoor (TMR) versus pasture (GRS) feeding on the beta-carotene content of butter.

		Indoor Feeding	Grass Feeding
Macro Elements (mg/100g)	Calcium	131.8[b]	**142.2[a]**
	Phosphorus	101[b]	**104[a]**
	Sodium	46.7[b]	**49.1[a]**
	Magnesium	13.0	13.4
Trace Elements (µg/kg)	Zinc	4,822	4,589
	Iron	331	542
	Copper	**76.9[a]**	60.3[b]
	Molybdenum	46.4	45.9
	Manganese	29.2[b]	**42.5[a]**
	Selenium	**27.1[a]**	15.7[b]
	Cobalt	0.82	0.80

Rows not sharing a common superscripted letter (a–b) differ significantly ($P < 0.05$)

Table 1: Variation in the concentration of macro-elements and trace-elements in milk derived from indoor TMR (indoor) and outdoor perennial ryegrass (grass) cow feeding systems. Table adapted from Gulati et al.[30]

Translation and significance to health

While research demonstrates that pasture feeding has a beneficial effect on the nutritional profile of milk and dairy products, clinical data demonstrating the effects of these products compared to indoor TMR-fed dairy on human health is lacking. In the proceedings from the *Teagasc Grass-Fed Dairy Conference 2018*, one point raised is that as milk is already a highly nutritious product, the changes resulting from grass-feeding alone may not be enough to have a further impact on chronic disease risk, particularly at current milk consumption levels. However, given the positive image and consumer perception of grass-fed dairy compared to its indoor TMR counterpart, this could help to encourage milk consumption, which would in turn assist in improving overall nutrient intake[34].

It remains to be seen, however, if there is a longevity effect of consuming milk with increased concentrations of the aforementioned nutrients on a regular basis over time. The significantly increased concentrations of CLA in pasture-derived milks is promising; however, despite positive research in this area, the exact mechanisms for the interaction between CLA and human health are still poorly understood. Several health claims relating to CLA have been submitted for approval to the European Food Safety Authority but, to date, none have been authorised due to insufficient evidence for substantiation.

The consumption of grass-fed dairy products, which have naturally enriched concentrations of n-3 fatty acids, should be beneficial in improving the overall ratio of n-6 to n-3 fatty acids in the human diet. However, the increases of n-3 intake from grass-fed milk may be too subtle in biological terms, particularly relative to the standard milk serving size. In more concentrated products, such as butter and cheddar cheese, the improvements in nutritional profile may have more magnitude when consumption is increased, offering greater potential for health benefits. Indeed, in the newly launched Food for Health Ireland-3 (FHI-3) research programme, grass-fed dairy is a primary topic of research and investigators hope to examine and characterise the impacts of pasture and non-pasture derived dairy products, relative to human health.

References:

1. Fox PF *et al.* (2015) Dairy Chemistry and Biochemistry. Springer International Publishing. Cham, Switzerland.
2. O'Brien D, Moran B, Shalloo L (2018) A national methodology to quantify the diet of grazing dairy cows. J Dairy Sci 101, 8595-8604.
3. Getter KL, Behe BK, Howard PH *et al.* (2015) Increasing Demand for Pasture-Based Dairy: What Attributes and Images Do Consumers Want? In *Re-Thinking Organic Food and Farming in a Changing World*, pp. 125-140: Springer.
4. O'Neill B, Deighton M, O'Loughlin B, *et al.* Effects of a perennial

ryegrass diet or total mixed ration diet offered to spring-calving Holstein-Friesian dairy cows on methane emissions, dry matter intake, and milk production. *J Dairy Sci* 2011; 94: 1941–1951.
5. Alothman M, Hogan SA, Hennessy D *et al.* (2019) The "Grass-Fed" Milk Story: Understanding the Impact of Pasture Feeding on the Composition and Quality of Bovine Milk. *Foods* 8, 350.
6. Smithers GW (2008) Whey and whey proteins—from 'gutter-to-gold'. *Int Dairy J* 18, 695-704.
7. Hsieh C-C, Hernández-Ledesma B, Fernández-Tomé S *et al.* (2015) Milk proteins, peptides, and oligosaccharides: effects against the 21st century disorders. *BioMed Res Int* 146840.
8. Mills S, Ross R, Hill C *et al.* (2011) Milk intelligence: Mining milk for bioactive substances associated with human health. *Int Dairy J* 21, 377-401.
9. Lindmark Månsson H (2008) Fatty acids in bovine milk fat. *Food Nutr Res* 52, 1821.
10. Palmquist D (2006) Milk fat: Origin of fatty acids and influence of nutritional factors thereon. In *Advanced Dairy Chemistry Volume 2 Lipids*, pp. 43-92: Springer.
11. O'Callaghan TF, Faulkner H, McAuliffe S *et al.* (2016) Quality characteristics, chemical composition, and sensory properties of butter from cows on pasture versus indoor feeding systems. *J Dairy Sci* 99, 9441-9460.
12. Fernandez ML, West KL (2005) Mechanisms by which dietary fatty acids modulate plasma lipids. *J Nutr* 135, 2075-2078.
13. Smith JG, Yokoyama WH, German JB (1998) Butyric acid from the diet: actions at the level of gene expression. *Crit Rev Food Sci* 38, 259-297.
14. German JB (1999) Butyric acid: a role in cancer prevention. *Nutrition Bulletin* 24, 203-209.
15. Haug A, Høstmark AT, Harstad OM (2007) Bovine milk in human nutrition–a review. *Lipids Health Dis* 6, 1.
16. Thorning TK *et al.* (2017) Whole dairy matrix or single nutrients in the assessment of health effects: current evidence and knowledge gaps. *Am J Clin Nutr*; 105: 1033-1045.
17. Harris WS (2015) n-3 and n-6 Fatty Acids Reduce Risk for Cardiovascular Disease. In *Preventive Nutrition*, pp. 255-271: Springer.
18. Patterson E, Wall R, Fitzgerald GF *et al.* (2012) Health Implications of High Dietary Omega-6 Polyunsaturated Fatty Acids. *J Nutr Metab* 2012, 16.
19. Molendi-Coste O, Legry V, Leclercq IA (2010) Why and how meet n-3 PUFA dietary recommendations? *Gastroenter Res Prac* 2011.
20. Benbrook CM, Butler G, Latif MA *et al.* (2013) Organic production enhances milk nutritional quality by shifting fatty acid composition: a United States–wide, 18-month study. PloS One 8, e82429.
21. Dilzer A, Park Y (2012) Implication of Conjugated Linoleic Acid (CLA) in Human Health. *Crit Rev Food Sci Nutr* 52, 488-513.
22. Siurana A, Calsamiglia S (2016) A metaanalysis of feeding strategies to increase the content of conjugated linoleic acid (CLA) in dairy cattle milk and the impact on daily human consumption. *Anim Feed Sci Tech* 217, 13-26.
23. Lawson RE, Moss AR, Givens DI (2001) The role of dairy products in supplying conjugated linoleic acid to man's diet: a review. *Nutr Res Rev* 14, 153-172.
24. McGuire M, McGuire M (2000) Conjugated linoleic acid (CLA): A ruminant fatty acid with beneficial effects on human health. *J Anim Sci* 77, 1-8.
25. Coleman J, Pierce KM, Berry DP *et al.* (2009) The influence of genetic selection and feed system on the reproductive performance of spring-calving dairy cows within future pasture-based production systems. *J Dairy Sci* 92, 5258-5269.
26. O'Callaghan TF, Hennessy D, McAuliffe S *et al.* (2016) Effect of pasture versus indoor feeding systems on raw milk composition and quality over an entire lactation. *J Dairy Sci* 99, 9424-9440.
27. Faulkner H, O'Callaghan TF, McAuliffe S *et al.* (2018) Effect of different forage types on the volatile and sensory properties of bovine milk. *J Dairy Sci* 101, 1034-1047.
28. O'Callaghan TF, Mannion DT, Hennessy D *et al.* (2017) Effect of pasture versus indoor feeding systems on quality characteristics, nutritional composition, and sensory and volatile properties of full-fat Cheddar cheese. *J Dairy Sci* 100, 6053-6073.
29. Panthi RR, Kelly AL, Hennessy D *et al.* (2019) Effect of pasture versus indoor feeding regimes on the yield, composition, ripening and sensory characteristics of Maasdam cheese. *Int J Dairy Tech* 72, 435-446.
30. Gulati A, Galvin N, Lewis E *et al.* (2018) Outdoor grazing of dairy cows on pasture versus indoor feeding on total mixed ration: Effects on gross composition and mineral content of milk during lactation. *J Dairy Sci* 101, 2710-2723.
31. Magan JB, Tobin JT, O'Callaghan TF *et al.* (2019) Physicochemical properties of whole milk powder derived from cows fed pasture or total mixed ration diets. *J Dairy Sci* S0022-0302(19)30721-0.
32. Field CJ, Blewett HH, Proctor S *et al.* (2009) Human health benefits of vaccenic acid. *App Physiol Nutr Metab* 34, 979-991.
33. Turpeinen AM, Mutanen M, Aro A *et al.* (2002) Bioconversion of vaccenic acid to conjugated linoleic acid in humans. *Am J Clin Nutr* 76, 504-510.
34. Givens I (2018) Milk and dairy foods produced from grass fed dairy cows: do they have health advantages? *Proceedings of the Grass Fed Dairy Conference*, 17-22.

New Resource

The NDC has produced a new patient leaflet to create awareness about dairy and blood pressure, endorsed by the Irish Nutrition and Dietetic Institute. The relationship between dairy intake and a healthy blood pressure has been established for some time. As result, dairy forms part of the internationally recognised DASH (Dietary Approaches to Stop Hypertension) diet. The new health promotion leaflet is available for health practitioners to share with their patients.

To request your free copy of 'Dairy & Blood Pressure' please email us on hello@ndc.ie. Copies can also be downloaded from our website **www.ndc.ie**.

Contact us....

THE NATIONAL DAIRY COUNCIL (NDC)

The National Dairy Council
The Studio, Maple Avenue,
Stillorgan, Co. Dublin, Ireland
Tel: +353 (0)1 290 2451
Email: info@ndc.ie
Web: www.ndc.ie

NDCIreland @NDC_ie

Mission: To deliver real and unique value to Irish dairy farmers by protecting and promoting the image, quality, taste and nutritional credentials of Irish dairy produce to a wide variety of audiences in a clearly defined, focused and effective manner.

FOOD FOR HEALTH IRELAND (FHI)

Food for Health Ireland
Science Centre South
University College Dublin
Tel: + 353 (0)1 716 2391
Email: fhi@ucd.ie
Web: www.fhi.ie

@fhi_tweets Food for Health Ireland

Mission: To leverage the world-class capabilities of the Irish academic partners, with the market expertise of the industry partners, into a pipeline of innovative, nutritional functional ingredients/products for the global food industry.