Rumen-derived Fatty Acids - What Makes Them Special

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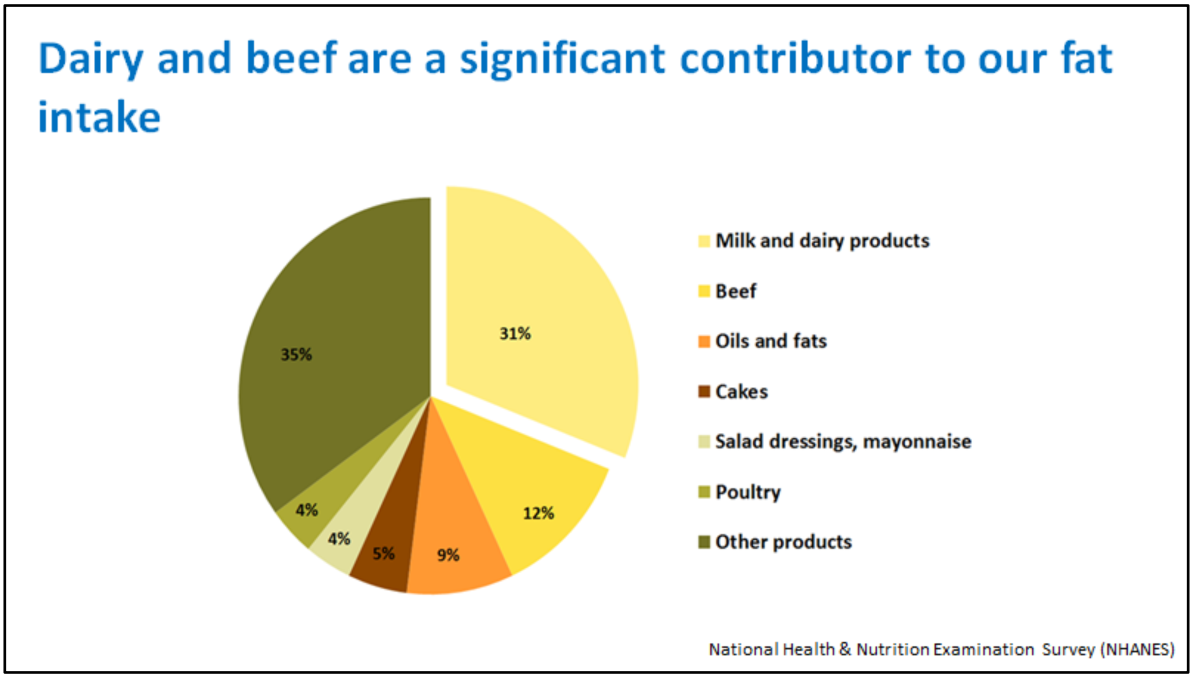
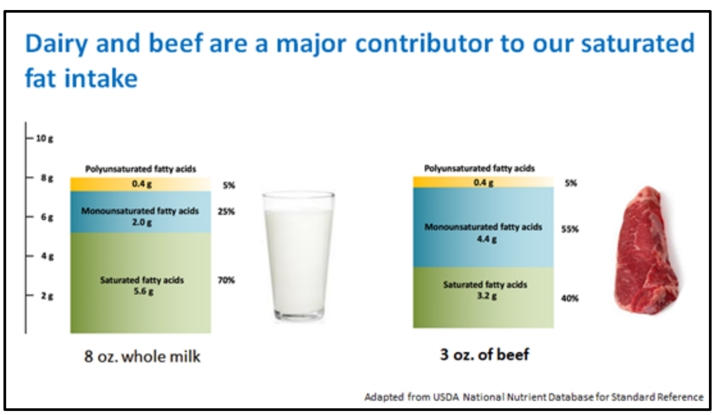
(Editor's Note: This paper is being summarized from the PowerPoint presentation given at the 2017 Conference. Narrative is limited as most of the slides were self-explanatory.)

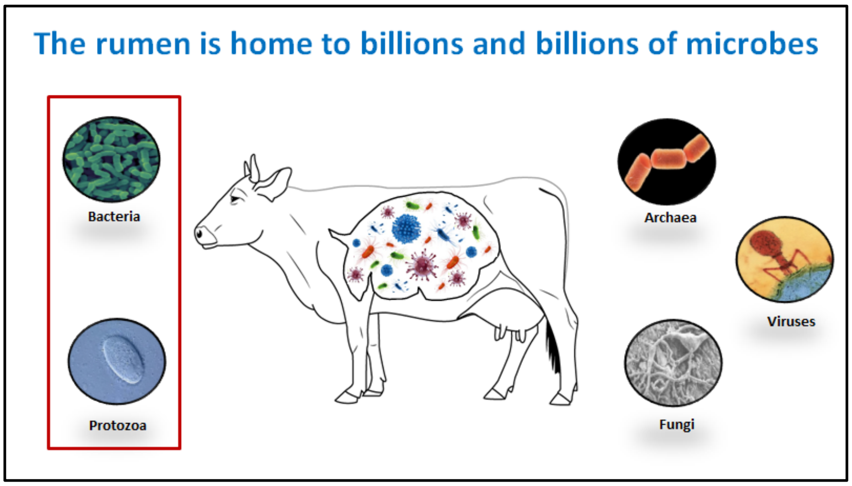




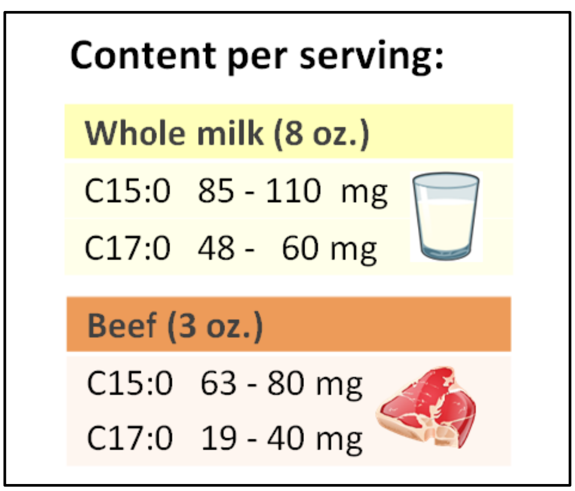
Fats from ruminant-derived products have been suffering from a negative nutritional image. Saturated fats have been under constant scrutiny for their potential role in the development of chronic diseases. Health authorities/agencies promote fat-reduced or fat-free dairy products of as part of a healthy diet. However, dairy and beef are a versatile source of bioactive nutrients from these major nutrient types: protein(peptides), vitamins, minerals, and fatty acids. Since we are looking particularly at fatty acids, they can be broken down further into these categories:

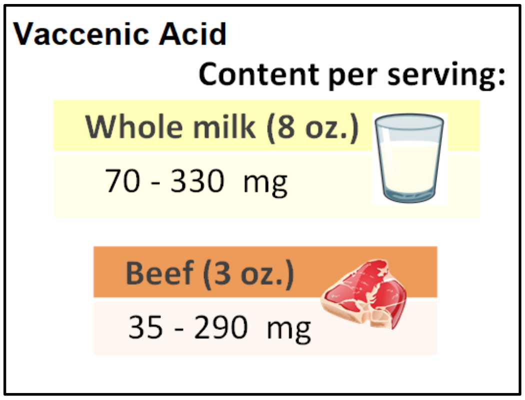
- Short-/medium-chain fatty acids
- Odd-chain fatty acids (OCFA)
- Branched-chain fatty acids (BCFA)
- Vaccenic acid
- Conjugated linoleic acids (CLA).

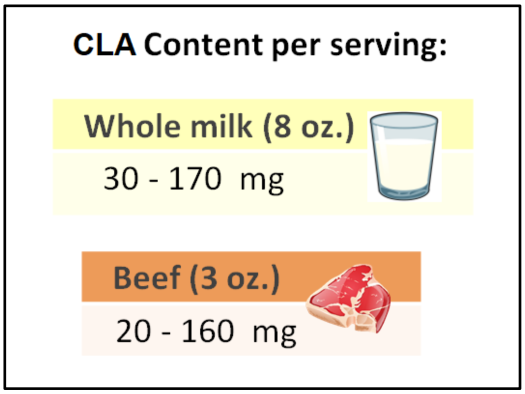
The last four listed are derived from the rumen of dairy and beef cattle.



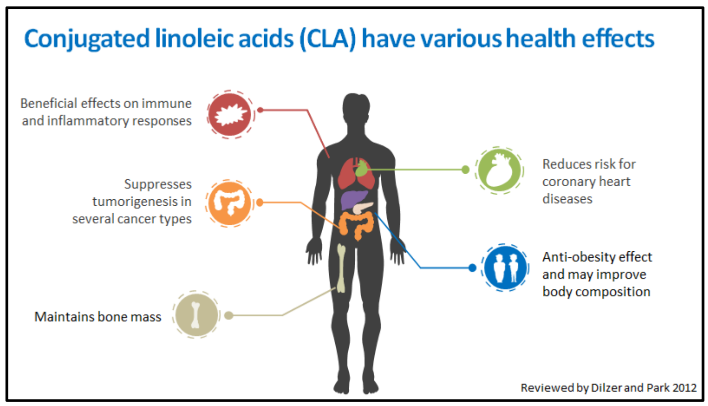
Rumen-microbe derived bioactive fatty acids are incorporated into meat and milk. Odd chain fatty acids (OC-FAs); pentadecanoic acid (C15:0) and heptadecanoic acid (C17:0), originate from rumen microbial biosynthesis. These two odd chain fatty acids are of particular interest in that they have been associated with reduced risk of coronary heart disease and type 2 diabetes, and for developing multiple sclerosis and Alzheimer's disease (Jenkins et al. 2015). Picture below shows the range of the two odd chain fatty acids in an 8 ounce glass of whole milk and a 3 ounce serving of beef.

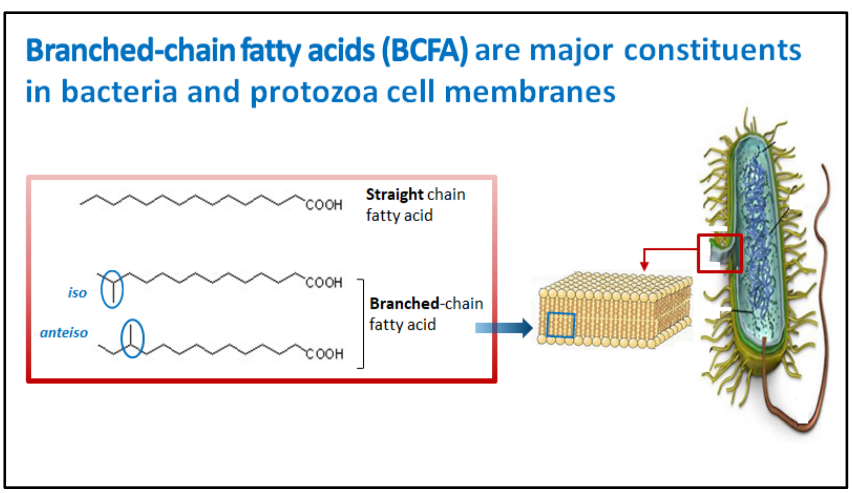






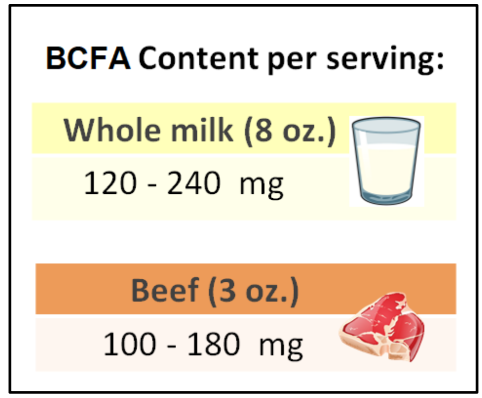
Vaccenic acid (C18:1 trans-11) is a principal ruminant trans fatty acid. It originates from rumen biohydrogenation of C18 unsaturated fatty acids [linolenic acid (C18:3 n-3), linoleic acid (C18:2 n-6), oleic acid (18:1 cis-9). First adjacent picture shows the range of vaccenic acid in an 8 ounce glass of milk and a 3 ounce serving of beef. Vaccenic acid is a dietary precursor to cis-9,trans-11 CLA. Cis-9,trans-11 CLA is the principal form of CLA found in ruminant-derived products. It originates from rumen biohydrogenation of linoleic acid and tissue synthesis from vaccenic acid. Second adjacent picture displays the range of CLA in an 8 ounce glass of milk and a 3 ounce serving of beef. CLA has several health benefits for those who consume it in their diet. These benefits are shown in the diagram below.



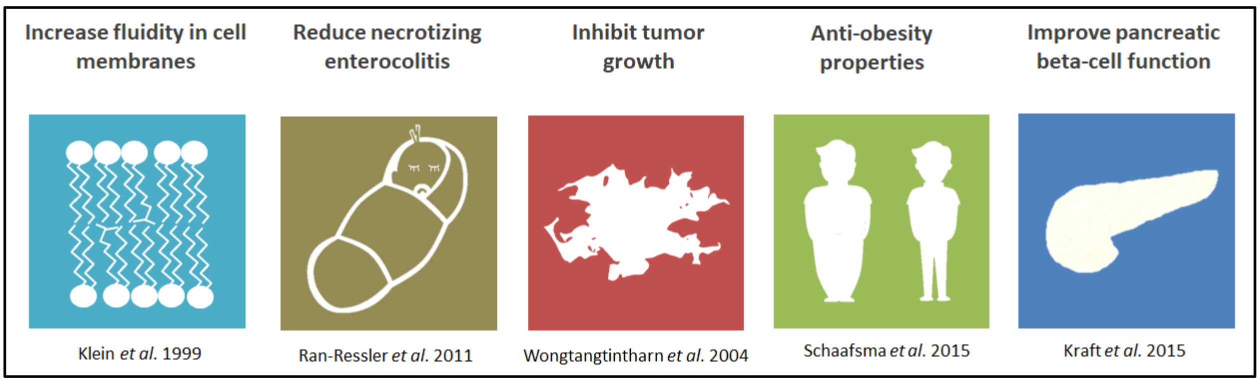


Ruminant products are a rich source of many branched-chain fatty acids (BCFA). Typical BCFA found in ruminant products are:

- iso 13:0
- anteiso 13:0
- iso 14:0
- iso 15:0
- anteiso 15:0
- iso 16:0
- iso 15:0, and
- anteiso 17:0.



Branched-chain fatty acids are an emerging class of bioactive fatty acids that exert various positive health effects. The picture below depicts the health promoting benefits.



Two main factors influence the content of bioactive fatty acids in ruminant-derived products, the animal and their diet (ration).

On the Animal side, these traits and body conditions impact the content of bioactive fatty acids in their products:

- ✓ Breed, genetics within breed
- ✓ Stage of lactation and type
- ✓ Diseases, udder infections
- ✓ Ruminal fermentation
- ✓ Activity and composition of the microbial populations

On the Diet side, it is the composition of the diet and the environmental conditions the animal is subjected to:

- ✓ Forage and grain intake
- ✓ Amount, composition, and type of dietary fat
- ✓ Dietary protein intake
- ✓ Energy intake
- ✓ Seasonal and regional effects

How does grazing pasture influence the content of bioactive fatty acids? Milk from cows grazing pasture is a very rich source of bioactive fatty acids. Table 1 characterizes herd size and milk production of confinement and summer pastured dairy herds in western Europe. Note milk yield and herd size is lower for dairy farms pasturing their milk cows in summer versus confinement dairy farms.

TABLE 1
Short Characterization of Cow Herds

Location	Farming	Altitude (m)	Milk yield (kg/yr)	Number of cows
1. Germany, Thuringia	Indoor-fed cows, silages and high concentrate rations, typical plain situation[a]	~200	>6000	>300
2. Germany, Thuringia	Organic farming, pasturing during the summer, only small amounts of concentrate[b]	~500	4000–5000	120–200
3. Switzerland, Alps	Summer pasturing without concentrate[c]	>1200, different places in Switzerland;	~4500	20–500
4. Switzerland, Alps	Summer pasturing without concentrate[c]	1275–2200, only L´Etivaz	~4500	30–50

[a]Most of the milk in Germany is produced under these conditions.
[b]About 5% of cows in Germany are stocked in organic farms.
[c]Summer pasturing of cows is practiced in the Alps regions of Switzerland, Austria, and Germany.

Kraft et al. 2003, *Lipids* 38 (6): 657-664.

Green leaves of immature pasture plants contain more lipid extract than leaves from mature forage. Due to the short vegetation period, the meadows at higher altitude in the Alps are physiologically young. Furthermore, under the lower environmental temperatures typical of the highlands, plant tissues contain a higher percentage of α-linolenic acid (Hawke, 1973). This is why when one examines Table 2 below, there is such a great increase in vaccenic acid and CLA, as much as tenfold higher, for high altitude (L'Etivaz) pastured cow's milk than for confined cows at a much lower altitude. Total BCFA is also significantly higher in high altitude pastured cow's milk than that of confined cow's milk, just not as dramatic of a difference. Most harvested forages, whether as ensilage or hay, are harvested at a later maturity and α-linolenic acid content in them is thereby lessened considerably. It also argues against grazing tall headed-out pasture grasses.

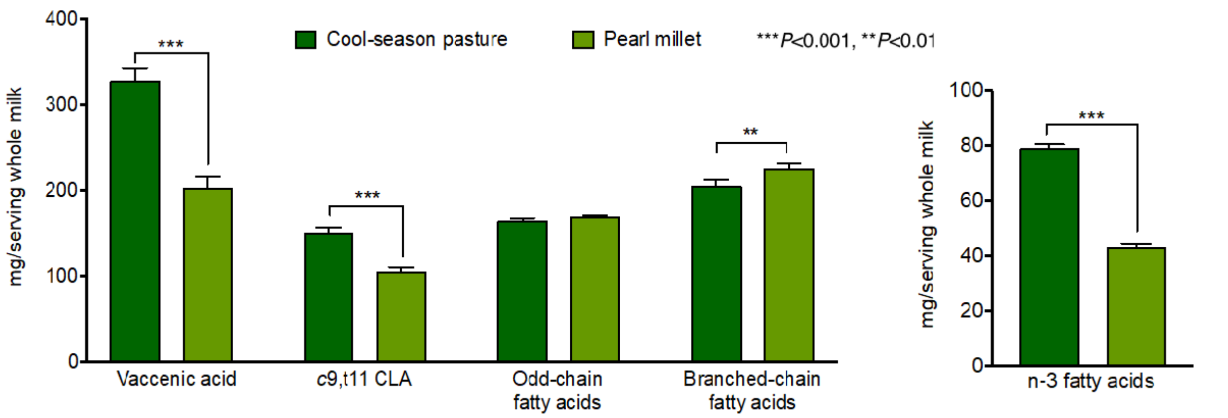
Table 2
Bioactive fatty acids in milk fat (values in mg/g fat)

Location	Germany		Switzerland	
	Indoor	Organic farming	Different Places	L'Etivaz
Vaccenic acid	3.48 ± 0.08^{a}	14.28 ± 6.68^{b}	32.31 ± 4.18^{c}	38.57 ± 3.41^{c}
*c*9,*t*11 CLA	2.76 ± 0.12^{a}	8.72 ± 3.50^{b}	22.94 ± 2.33^{c}	26.70 ± 1.08^{d}
ΣBCFA	35.87 ± 1.57^{a}	40.70 ± 1.89^{b}	45.12 ± 1.95^{c}	48.06 ± 2.08^{c}
C15:0	10.81 ± 0.18^{a}	$10.83 \pm 0.61^{a,c}$	$12.63 \pm 0.21^{b,c}$	13.22 ± 1.48^{b}
C17:0	5.93 ± 0.07^{a}	5.88 ± 0.14^{a}	7.49 ± 0.24^{b}	6.94 ± 0.42^{b}

Values in a row not sharing a common superscript roman letter differ, $P < 0.05$.

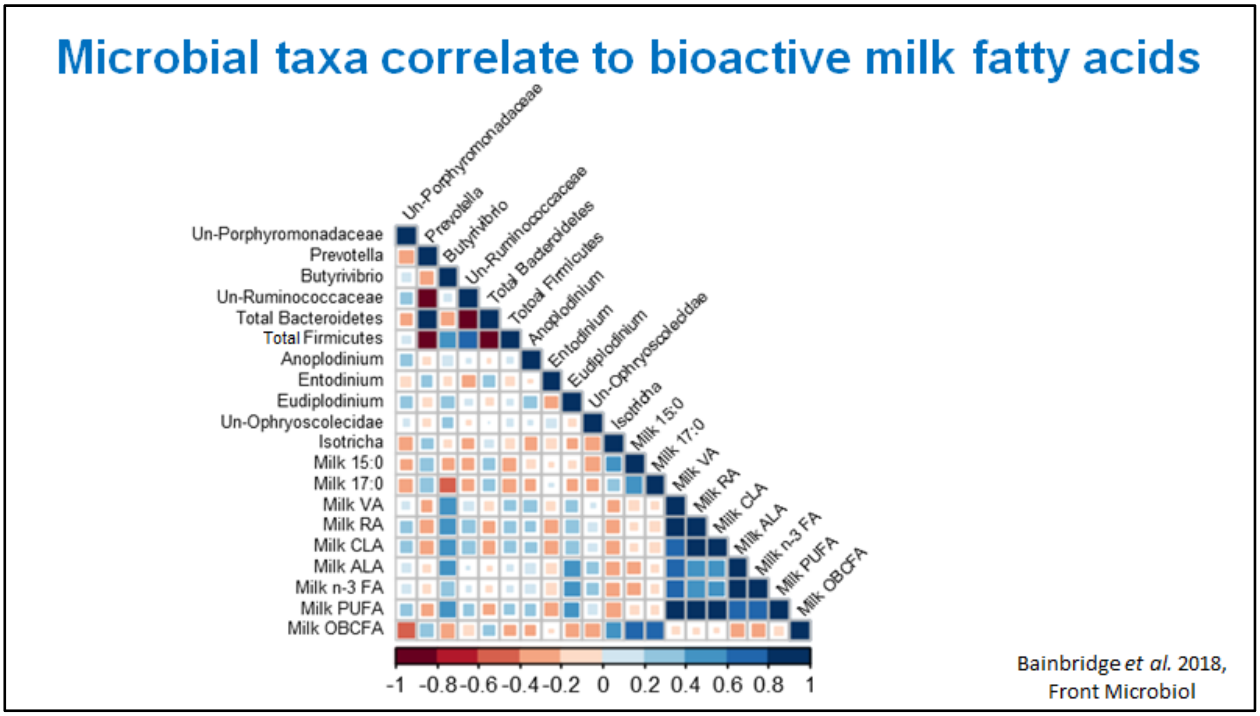
Kraft et al. 2003, *Lipids* 38 (6): 657-664.

Work done at the University of Vermont (shown below) also found milk contents of vaccenic acid, CLA, and omega-3 (n-3) fatty acids were higher when cows grazed on a cool season pasture as opposed to a summer annual, pearl millet, a warm season grass.



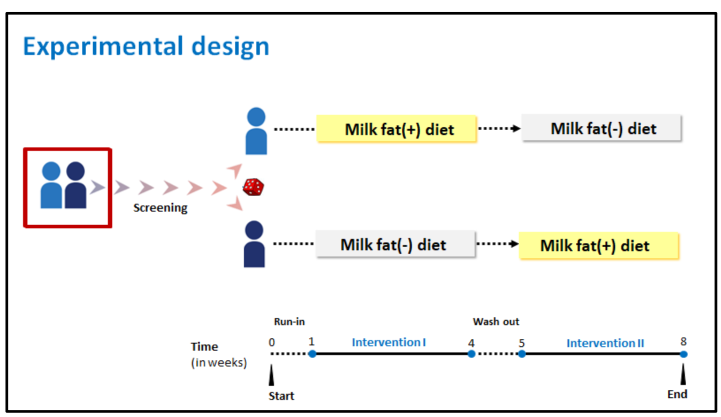
Bainbridge *et al.* 2017, *Food Chem* 217: 750-755.

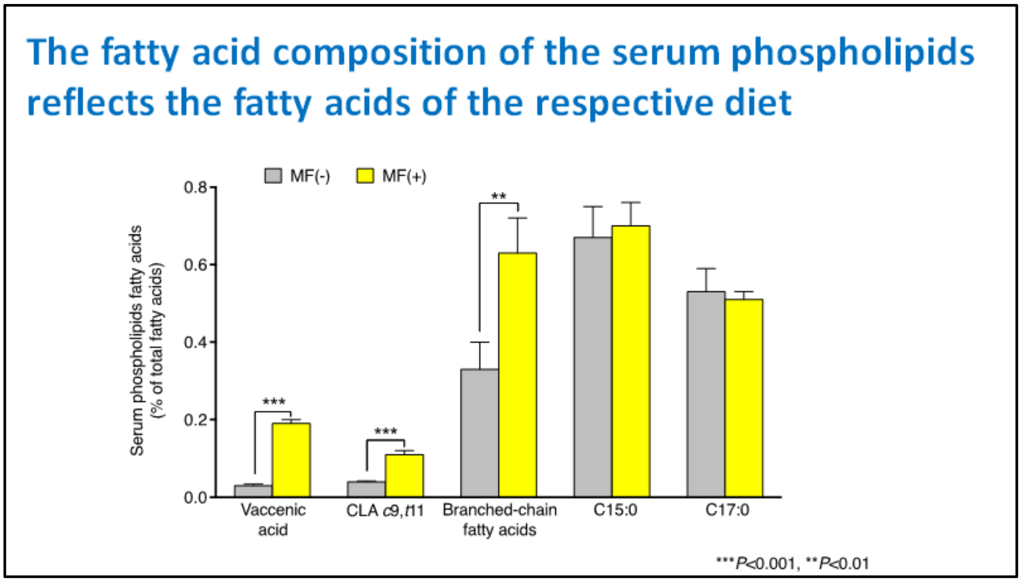
The figure below displays a Pearson correlation matrix between bacterial and protozoal taxa and milk fatty acids of cows grazing a cool-season pasture and pearl millet. The scale of the colors is denoted as follows: the more positive the correlation (closer to 1), the darker the shade of blue; the more negative the correlation (closer to −1), the darker the shade of red. Data were used from the last week of each period (n = 5 for CSP; n = 10 for PM). Un, Unclassified; VA, Vaccenic acid; RA, Rumenic acid; CLA, Conjugated linoleic acids; ALA, a-Linolenic acid; PUFA, Polyunsaturated fatty acids; OBCFA, Odd-and-Branched-chain fatty acids. The proportion of 17:0 in milk was negatively correlated with Butyrivibrio (R = −0.42; P < 0.05 (medium dark red). The milk proportions of 15:0 and 17:0 were positively correlated with the bacterial genus, Prevotella (R = 0.43, and 0.43, respectively; P < 0.05) (medium blue). Milk VA, RA, and total CLA positively correlated with bacteria of the genus Butyrivibrio (R = 0.58, 0.50, 0.47, respectively; P < 0.01 (medium dark blue). The upshot of this is rumen microorganisms synthesize unique FA such as OBCFA, and create biohydrogenation intermediates (e.g., VA and CLA) that are incorporated into milk fat, making it the most distinctive dietary fat in nature. These FA impart beneficial health effects in humans consuming ruminant-derived-food products. Altering microbial communities and their FA metabolism through diet modification can potentially enhance the quantity and profile of these bioactive FA that are available for incorporation into milk and meat (Bainbridge, 2018).



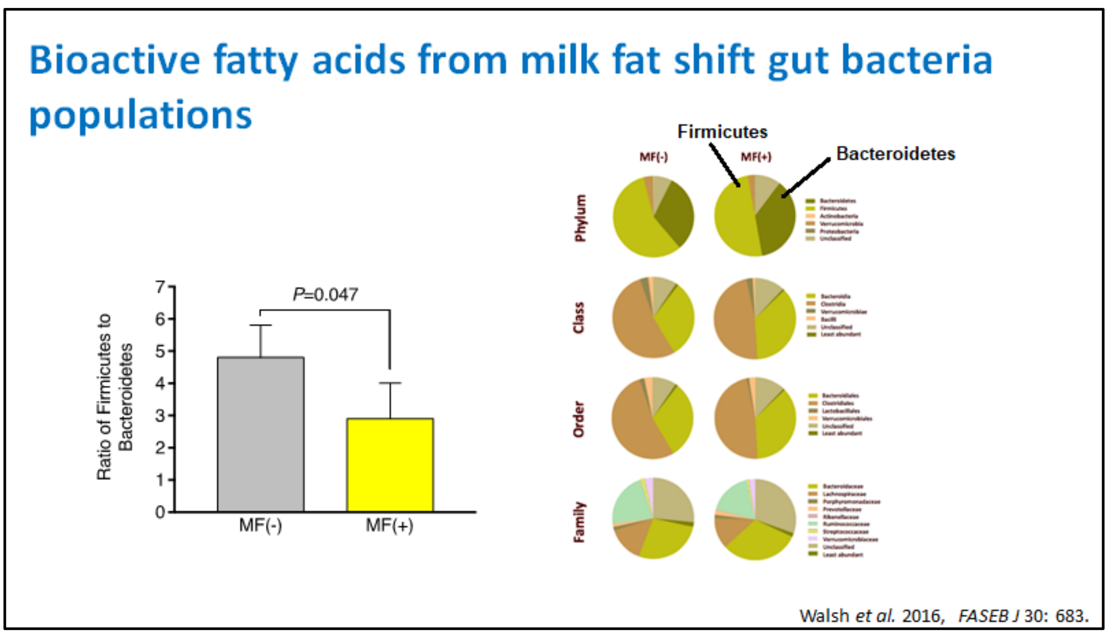
We examined the effects of consuming a diet comprised of bioactive FA from milk fat on metabolic health markers by doing a study whose purpose was to determine if unique, rumen bacteria-derived FA found in dairy fat *per se* alter glucose homeostasis. The study population comprised of 10 women and 11 men who were healthy and of normal weight. Their ages ran from 18 to 40 years old. Experimental design diagram is shown above. A standardized diet was used during the study to carefully ensure the diet differences was only based on the presence or absence of milk fat in the diet. Study endpoints (outcome measurements) were:

- Primary endpoints
  - Blood glucose and insulin levels *via intravenous glucose tolerance test
  - Blood triglyceride and cholesterol levels
- Explanatory endpoints
  - Gut microbes
  - Inflammation markers





The outcome of the study was to show that vaccenic acid, CLA, and branched-chain FA were significantly elevated in the blood of people who had milk fat in their diet over those deprived of milk fat. These 3 fatty acids promote good health.



A study done by Walsh et al. (2016) demonstrated that bioactive fatty acid can shift gut bacteria populations. In the figure above, a diet with milk fat in it changed the ratio of Firmicutes to Bacteroidetes over that of a diet without milk in it. Why is this important? These two types of bacteria regulate fat absorption in the gut. Researchers observe a higher ratio of Firmicutes to Bacteroidetes in obese humans, while in leaner humans, a higher ratio of Bacteroidetes to Firmicutes is found. Therefore, the right type of milk fats in the human diet can make it easier to lose fat weight by changing the gut's bacterial makeup.
Take Home Messages:

- ✓ Ruminant-derived products are unique as they consist of a variety of bioactive fatty acids with health promoting attributes.
- ✓ The content of rumen-derived bioactive fatty acids can be altered via nutritional strategies – especially pasture regimes.
- ✓ Understanding the complex interplay between rumen microbes and their contributions to the fatty acid pool of ruminant products is key to establishing novel strategies to optimize the content of bioactive fatty acids in milk and meat for human health maintenance and promotion.

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