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# Introduction to Flaxseed Health Aspects And Product Applications

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# Outline

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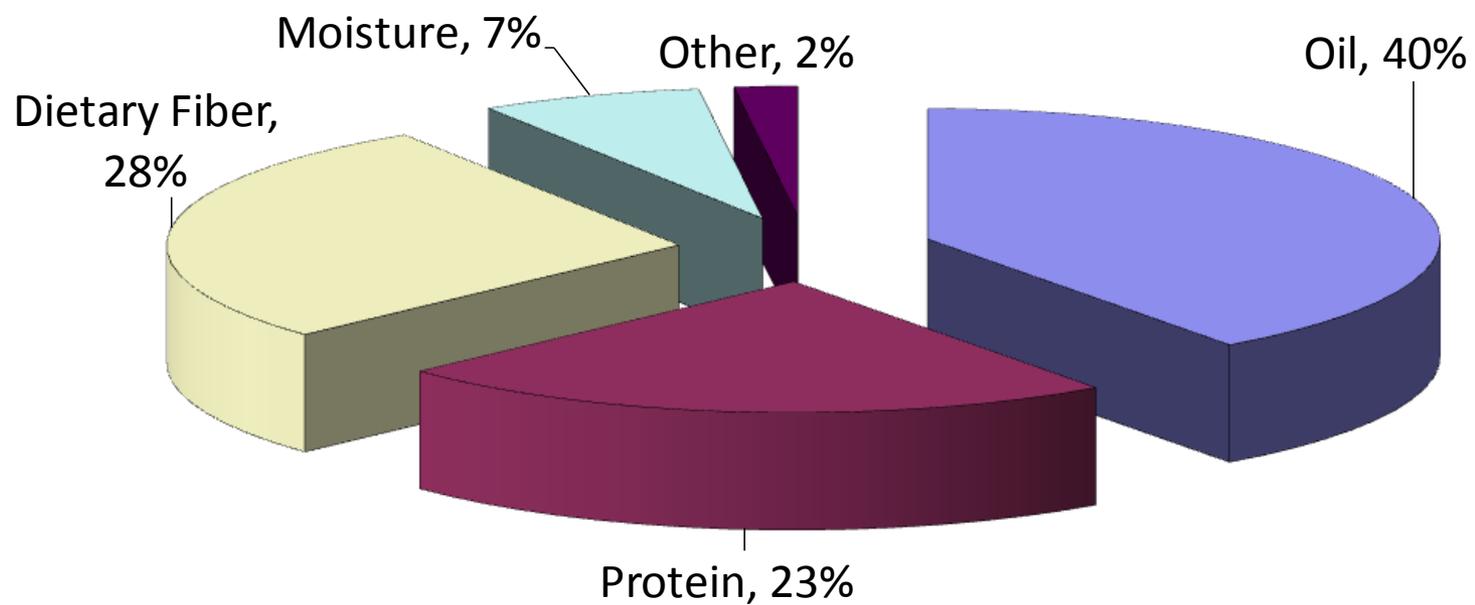
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- **Flaxseed Components**
- **Location of Components within Flaxseed**
- **Stability of Nutrients**
- **Health Aspects of Flaxseed**
- **Application**



# Proximate Composition of Flaxseed





# Flaxseed Nutrients



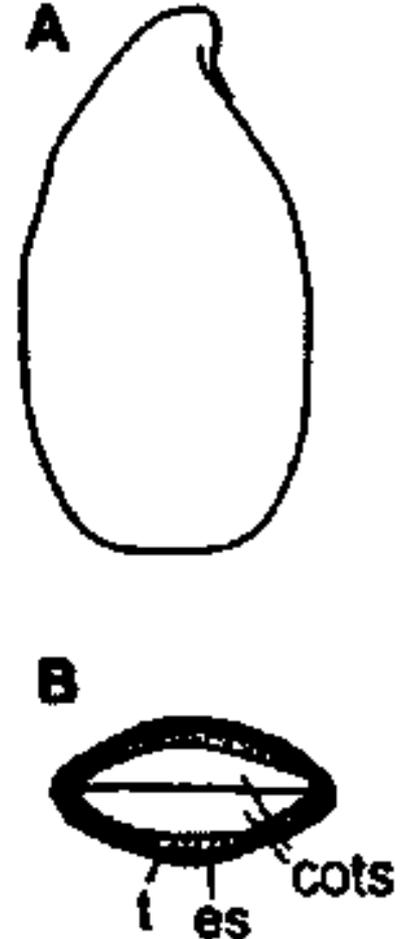
## USDA National Nutrient Database, Release 20 (2007)

Nutrient	Units	1 tbsp whole 10.3g	1 tbsp ground 7g
<b>Proximates</b>			
Water	g	0.72	0.49
Energy	kcal	55	37
Energy	kJ	230	156
Protein	g	1.88	1.28
Total lipid (fat)	g	4.34	2.95
Ash	g	0.38	0.26
Carbohydrate	g	2.97	2.02
Fiber, total dietary	g	2.8	1.9
Calcium, Ca	mg	26	18
Iron, Fe	mg	0.59	0.4
Potassium, K	mg	84	57
Sodium, Na	mg	3	2
Vitamin C	mg	0.1	0

- **Flaxseed Structure**

- Cotyledons (cots)
- Endosperm (es)
- Testa or hull (t)

Daun et al. 2003. In Flaxseed in Human Nutrition.





# Lipid Composition



- **Total Lipid – 35 to 42% (35 – 42 g oil/ 100 g flaxseed)**
  - ✓ **Neutral lipid – 96.3% (33.7 – 40.4 g/100 g flax)**
  - ✓ **Polar lipids – 2.8% (0.95 – 1.1 g/100 g flax)**
  - ✓ **Complex lipids - 1% (0.4 g/100 g flax)**



# Lipid Composition



- **Neutral lipids – 33.7 to 40.4 g/100 g flax**
  - ✓ **Free fatty acids – 0.3% of neutral lipids**
  - ✓ **Monoacylglycerols – 1.4% of neutral lipids**
  - ✓ **Diacylglycerols – 2.3% of neutral lipids**
  - ✓ **Triacylglycerols – 94.7% of neutral lipids**
  - ✓ **Sterols – 1.3% of neutral lipids**



# Lipid Composition



- **Triacylglycerols – 32 to 38 g / 100 g flaxseed)**

TRIACYLGLYCEROL DISTRIBUTION OF FLAXSEED<sup>a, b</sup>

Triacylglycerols (TG)	%	Triacylglycerols (TG)	%
LnLnLn	30.4	OLnP	3.1
LaLnLn	18.7	LnLaP	3.0
OLnLn	13.5	SLaLa	1.1
LnLnP	6.9	OLaLa	1.0
OLaLn	5.9	LaLaLa	0.9
LaLaLn	5.3	OLaO	0.8
OLnO	4.2	LaOP	0.6
SLnLn	4.1	PLnP	0.5

<sup>a</sup> Adapted from Holcapek *et al.* (2004)

<sup>b</sup> P = Palmitic acid, S = Stearic acid O = Oleic acid, La = Linoleic acid and Ln = Linolenic acid



# Carbohydrates



- **Total Carbohydrates – 29 to 30% (~30 g/100 g)**
  - ✓ **Dietary Fiber - 28 % (28 g/100 g)**
    - ❖ **Soluble – 20-40% of the dietary fiber**
    - ❖ **Insoluble – 60-80% of the dietary fiber**
  
  - ✓ **Sugars – 1-2 % (~2 g /100 g)**
    - ❖ **Sucrose – 75% of the sugars**
    - ❖ **Glucose – 25% of the sugars**



# Carbohydrates



- **Mucilage (i.e. dietary fiber) – 8% of seed weight**
  - ✓ **Fiber component**
  - ✓ **Located in the hull - Epidermal layer (outer most)**
  - ✓ **Interest in mucilage / gum**
    - ❖ **Food hydrocolloid**
    - ❖ **Emulsifier**
    - ❖ **Cholesterol reduction**



# Carbohydrates



- **Mucilage (i.e. dietary fiber) – 8% of seed weight**
  - ✓ **Acidic fraction (AF) – 67%**
    - ❖ **L-Rhamnose – 38 to 54.4% of AF**
    - ❖ **D-Galacturonic acid – 23 to 25% of AF**
    - ❖ **L-Galactose – 20.6 to 23.4% of AF**
    - ❖ **L-Fucose – 14 to 15% of AF**
  - ✓ **Neutral fraction (NF) – 33%**
    - ❖ **D-xylose – 58 to 62.8 % of NF**
    - ❖ **L-Arabinose – 33% of NF**
    - ❖ **D-Galactose – 9% of NF**



# Protein



PROTEIN CONTENT OF DIFFERENT FLAXSEED CULTIVARS<sup>a</sup>

Poland		Canada		USA	
Kozłowska, 1989		Oomah and Mazza, 1993		Hettiarachchy <i>et al.</i> , 1990	
Variety	Protein %	Variety	Protein <sup>b</sup> %	Variety	Protein %
Avangard	24.7	Linott	19.81	Clark	27.3
Reina	25.2	Noralta	19.82	Culbert	30.0
Viking	25.6	Dufferin	18.42	Dufferin	31.6
Ottawa	25.8	McGregor	19.07	Flor	31.0
Hera	27.4	NorLin	19.49	Linott	26.9
Zielona	27.9	NorMan	19.45	Linton	29.4
Bionda	28.0	Vimy	19.03	McGregor	27.1
LCSD200	28.2	Andro	19.89	Neche	29.5
Svapo	28.6	Somme	19.67	Norlin	28.1
–	–	Flanders	19.33	Norman	27.0
–	–	AC Linora	20.18	Verne	29.5

<sup>a</sup>Protein contents are calculated on dry basis.

<sup>b</sup>N × 6.5.



# Protein



PROTEIN CONTENT OF FLAXSEED FRACTION<sup>a</sup>

Fractionation	Protein %	Cultivar	Reference
Seed	19.2	NorMan, Linola™947, McGregor, NorLin,	Oomah and Mazza, 1997
Dehulled seed	21.8	Omega, Flanders, and Vimy	
Hull	17.3		
Dehulled seed	23.9	NorMan	Lei <i>et al.</i> , 2003
Meal	22.9		
Hull	20.3	–	Bhatty and Cherdklatgumchal, 1990
Laboratory-prepared meal	43.9	Norlin, NorMan, and McGregor	
Commercial meal	34.7	–	
Dehulled meal	50.0	–	Krause <i>et al.</i> , 2002
Dehulled meal	48.9	Khategaon	Madhusudhan and Singh, 1983
Meal	49.0	Viking	Sammour, 1999

<sup>a</sup>Protein data are based on dry basis.

Hall et al. 2006, in *Advances in Food and Nutrition Research*, Vol. 51.



# Protein



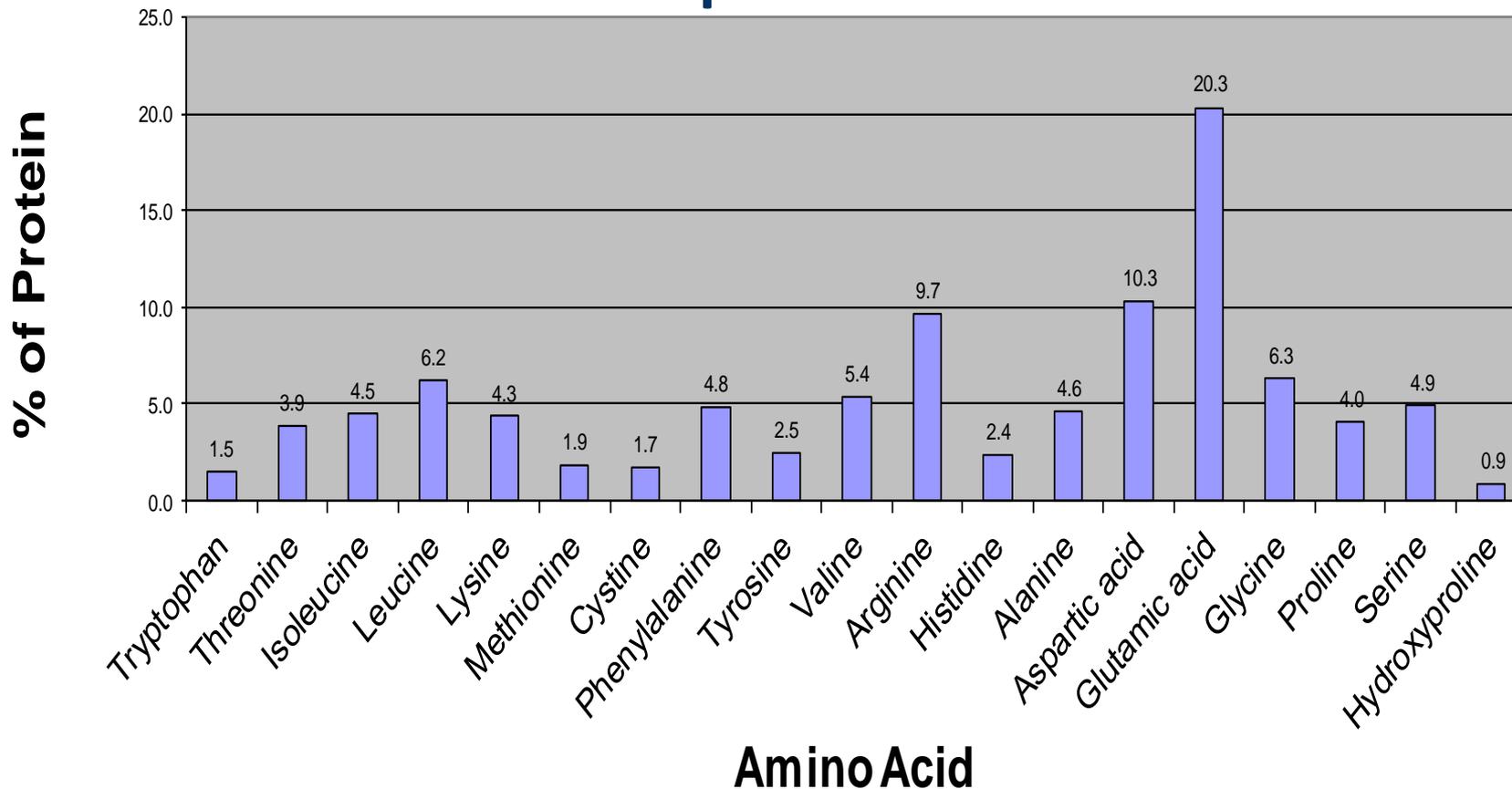
- **Protein Content – 10.5 to 31% (10.5 to 31 g/100 g flaxseed)**
  - ✓ **Albumins – 20 to 40 % of protein**
  - ✓ **Globulins – 42 to 73.4% of protein**



# Protein



## Amino Acid Composition

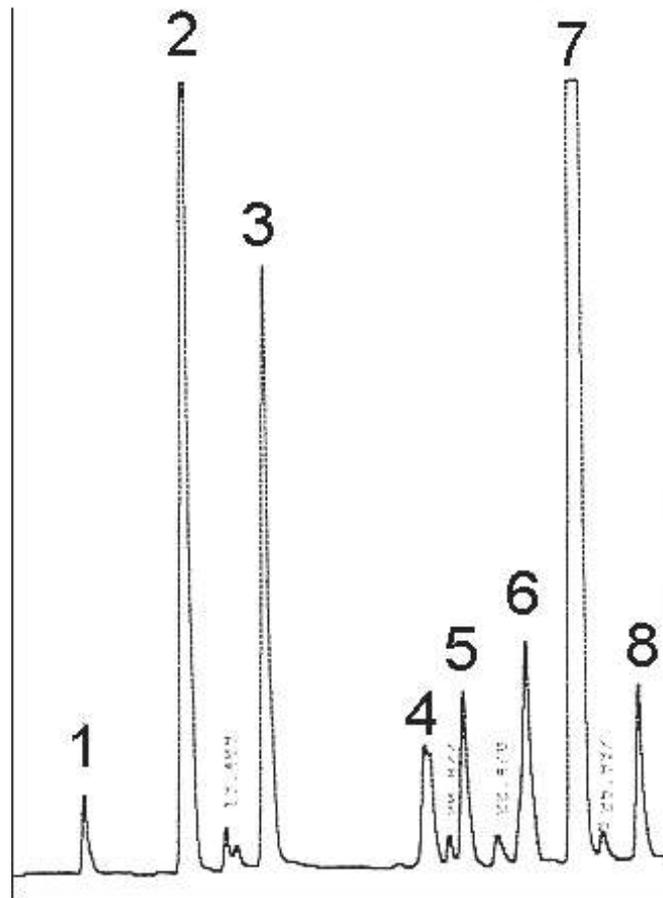




# Phytochemicals



<u>Compound</u>	<u>Number</u>
Protocatechuic acid (8.2 min)	1
p-Hydroxybenzoic acid (12.3)	2
Chlorogenic acid (15.1)	3
Vanillin (20.0)	4
p-Coumaric acid (21.4)	5
Ferulic (24.1)	6
SDG (25.0)	7
Sinapic acid (27.7)	8





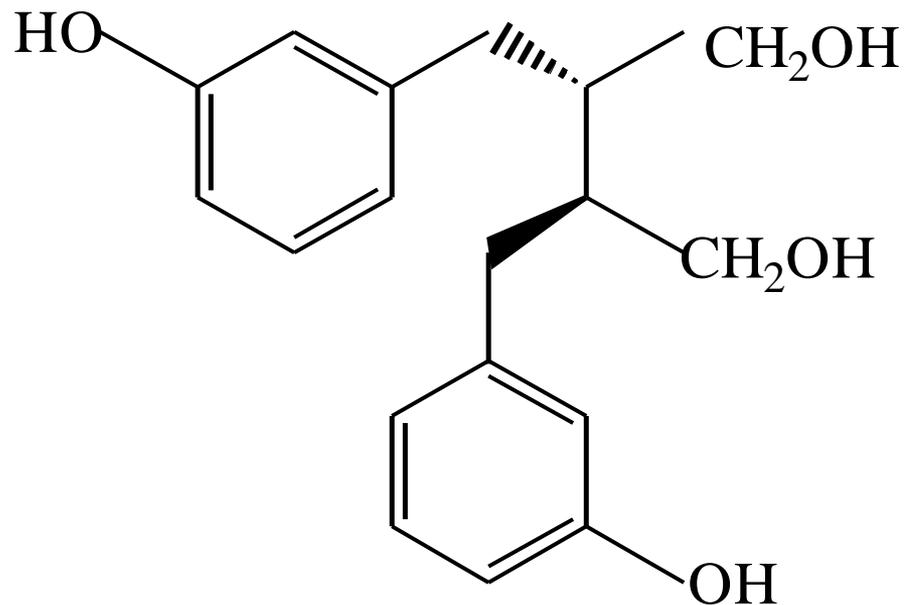


# Phytochemicals

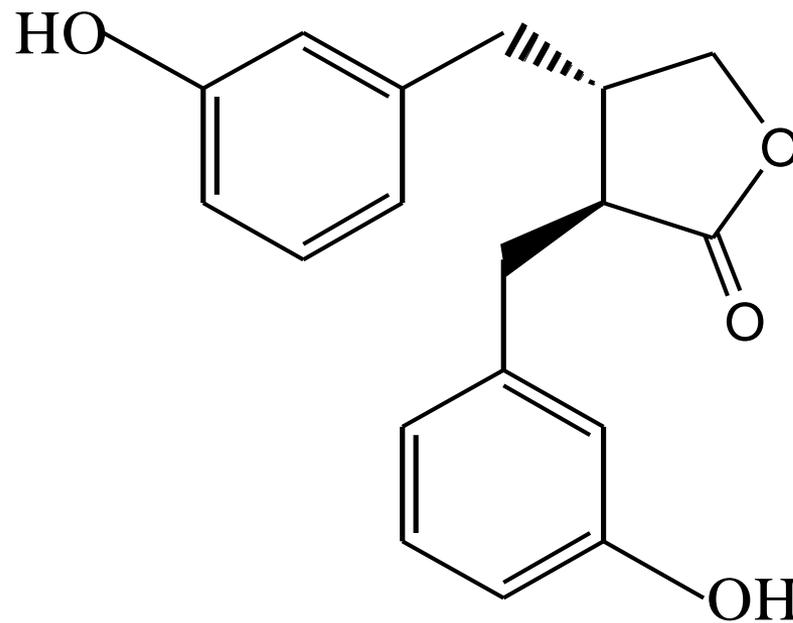


- **Lignans - Secoisolariciresinol diglucoside (SDG)**
  - ✓ **Whole seed & flours – 0.29 to 30 mg/g flaxseed**
  - ✓ **Madhusudhan et al (2000) reported a mechanical separation method**
    - ❖ **Whole seed – 12.9 mg/g (Neché) & 14.3 mg/g (Omega)**
    - ❖ **Hull-rich fraction - 27.6 mg/g (Neché) & 23.8 mg/g (Omega)**
  - ✓ **Hall and Shultz (2001) reported a solvent separation method**
    - ❖ **Defatted flaxseed extract – 47.9 mg/g**
    - ❖ **Non-defatted extract – 26.5 mg/g**

- Lignans conversion

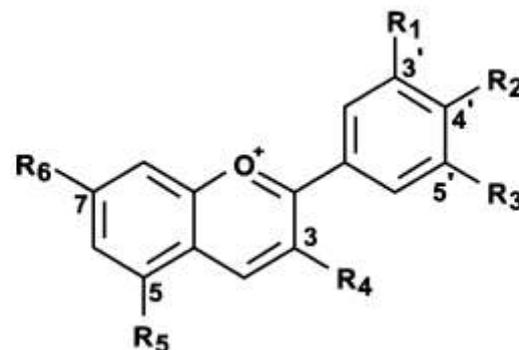


Enterodiol



Enterolactone

- Flavonoids

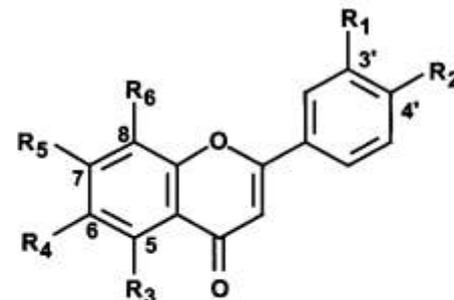
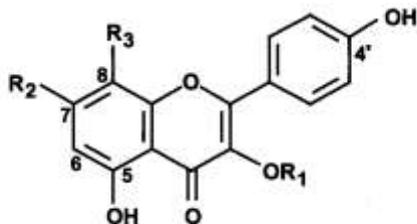


	Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	R <sub>6</sub>
65	3-Glucorutinosyl pelargonidin	H	OH	H	O-glu-rut	OH	OH
66	3-Glucorutinosyl cyanidin	OH	OH	H	O-glu-rut	OH	OH
67	3-Glucorutinosyl delphinidin	OH	OH	OH	O-glu-rut	OH	OH
68	3-tri-Glucosyl pelargonidin	H	OH	H	O-tri-glu	OH	OH
69	3-tri-Glucosyl cyanidin	OH	OH	H	O-tri-glu	OH	OH
70	3-tri-Glucosyl delphinidin	OH	OH	OH	O-tri-glu	OH	OH
71	3-di-Glucosyl delphinidin	OH	OH	OH	O-di-glu	OH	OH
72	3-Rutinosyl pelargonidin	H	OH	H	O-rut	OH	OH
73	3-Rutinosyl cyanidin	OH	OH	H	O-rut	OH	OH
74	3-Rutinosyl delphinidin	OH	OH	OH	O-rut	OH	OH
75	3-Glucosyl pelargonidin	H	OH	H	O-glu	OH	OH
76	3-Glucosyl cyanidin	OH	OH	H	O-glu	OH	OH
77	3-Glucosyl delphinidin	OH	OH	OH	O-glu	OH	OH
78	3-Xylorutinosyl delphinidin	OH	OH	OH	O-xyl-rut	OH	OH

rut = rutinose, xyl = xylose

Westcott and Muir, 2003;  
in Flax The genus *Linum*

## • Flavonoids



Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>
79 3,7-Dimethoxy-herbacetin	CH <sub>3</sub>	OCH <sub>3</sub>	OH
80 3,7-Diglucopyranosyl-kaempferol	glu	O-glu	H
81 3,8-O-Diglucopyranosyl-herbacetin	glu	H	O-glu

Name	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	R <sub>4</sub>	R <sub>5</sub>	R <sub>6</sub>
82 Orientin	OH	OH	OH	H	OH	C-glu
83 Iso-orientin	OH	OH	OH	C-glu	OH	H
84 Vitexin	H	OH	OH	H	OH	C-glu
85 Iso-vitexin	H	OH	OH	C-glu	OH	H
86 Vicenin-1	H	OH	OH	C-xyl	OH	C-glu
87 Vicenin-2	H	OH	OH	C-glu	OH	C-glu
88 Lucenin-1	OH	OH	OH	C-xyl	OH	C-glu
89 7-Rhamnosyl-lucenin-2	OH	OH	OH	C-glu	O-rham	C-glu
90 3',4'-Dimethoxy-7-rhamnosyl-luteolin	OCH <sub>3</sub>	OCH <sub>3</sub>	OH	H	O-rham	H
91 Linoside A	OH	OH	OH	H	OH	C-glu-2"rham-6"-Ac
92 Linoside B	OH	OH	OH	H	OH	C-glu-2"rham

rham = rhamnose

**Westcott and Muir, 2003;**  
**in Flax The genus *Linum***

Figure 3.12 Flavonoids from *Linum* spp.



# Why Flaxseed In Functional Foods?



- **Health Benefits - ALA**

- ✓ **Lowers Coronary Heart Disease Risk**

- ❖ **Nurses Health Study**

- **Higher intake of ALA = associated with a lower relative risk of fatal and non-fatal myocardial infarction**

*Hu, et al. 1999. Am. J. Clin. Nutr. 69:890*

- ❖ **Health Professional Follow-up Study**

- **1% increase in ALA intake =40% reduction in non-fatal CHD**

*Ascherio, et.al. 1996. Br. Med. J. 313:84*



# Why Flaxseed In Functional Foods?



- **Health Benefits - ALA**
  - ✓ **Lowers Coronary Heart Disease Risk**
    - ❖ **Cohort – Survivors of a myocardial infarction**
      - **75% reduction in non-fatal myocardial infarctions**

*Renaud, et.al. 1995. Am. J. Clin. Nutr. 61:1360S.*



# Why Flaxseed In Functional Foods?



- **Health Benefits - ALA**
  - ✓ **Lowers Coronary Heart Disease Risk**
    - ❖ **Total Blood Total Cholesterol Levels**
    - ❖ **Low Density Lipoprotein Cholesterol**
    - ❖ **Triglycerides**

*Chan, et al., 1991. Amer. J. Clin. Nutr. 53, 1230.*

*Chan, et al., 1993. Lipids. 28: 811.*



# Why Flaxseed In Functional Foods?



- **Health Benefits - ALA**

- ✓ **Inhibition of Atherosclerotic Plaques**

*Jacob, R., et al. 1997. Basic Res Cardiology. 92(4): 223.*

- ✓ **Reduction in Blood Clotting**

*Lanzmann-Petithory, D. 2001. J. Nutrition, Health, & Aging. 5(3):179.*

- ✓ **Inverse association between ALA intake and plasma concentrations of C-reactive protein (a marker for inflammation)**

*Lopez-Garcia et al., 2004. J Nutr. 134, 1806-1811.*

*Bemelmans et al. 2004. Am. J. Clin. Nutr. 75, 221-227.*



# Why Flaxseed In Functional Foods?



- **Health Benefits - Lignans**

- ✓ Reduce hormone-dependent cancers - breast, endometrial and prostate

*Thompson, 2004. Flax Institute of the United States*

*Thompson 2003. In: Flaxseed in Human Nutrition (chapter 9).*

*Jungstrom et al. 2007. Clin. Cancer Res. 13:1061-1067.*

- ✓ Reduction in PSA scores and tumor-cell proliferation in men on a 30g of flaxseed / day

*Wahnefried, W. et al, 2001. , Journal of Urology 58:47.*



# Why Flaxseed In Functional Foods?



- **Health Benefits - Lignans**

- ✓ **Decreases rate of bone resorption**

*Arjmandi, B.H. et al. 1998. JANA. 1(2):27.*

- ✓ **Decreases the level of glycated hemoglobin A1c concentration in blood**

*Pan et al. 2007. PLoS ONE. 2(11):e1148.*

*doi.10.1371/journal.pone.0001148.*



# Why Flaxseed In Functional Foods?



- **Health Benefits – flaxseed consumption**

- ✓ **Decreases postprandial glucose response and insulin resistance**

*Cunnana et al. 1993. Br. J. Nutr. 69, 443-453. Bloedon et al., 2008. J Amer. Coll. Nutr. 27, 65-74.*

- ✓ **Decreases the level of cholesterol**

*Cunnana et al. 1993. JANA. 1(2):27. Arjmandi et al. 1998. Nutr. Res. 18, 1203-1214. Jenkins et al. 1999. Am. J. Clin. Nutr. 69, 395-402. Lucas et al., 2002. J. Clin. Endocrinol. Metab. 87, 1527-1532. Lemay et al. 2002. Obstet. Gynecol. 100, 495-504. Dodin et al. 2005. J. Clin. Endocrinol. Metab. 90, 1390-1397.*



# Why Flaxseed In Functional Foods?



- **Health Benefits – flaxseed consumption**

- ✓ **Decreases lipoprotein A**

*Cunnana et al. 1993. Br. J. Nutr. 69, 443-453. Bloedon et al., 2008. J Amer. Coll. Nutr. 27, 65-74.*

- ✓ **Tumor and cancer reduction**

*Bommareddy et al. 2009. Nutr. Cancer. 61, 276-283.*

*Thompson et al (2003) - 5-10% flaxseed was effective against indicators of breast cancer.*



# Why Use Flaxseed In Foods?



- **Unique Opportunities**
  - ✓ **Omega-3 enhancement**
  - ✓ **Dietary fiber enhancement**
  - ✓ **Lignans enhancement**



# Why Use Flaxseed In Foods?

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- **Challenges**
  - ✓ **Sensory Impact**
  - ✓ **Shelf Life Concerns**



# Flaxseed in Foods - General Approach



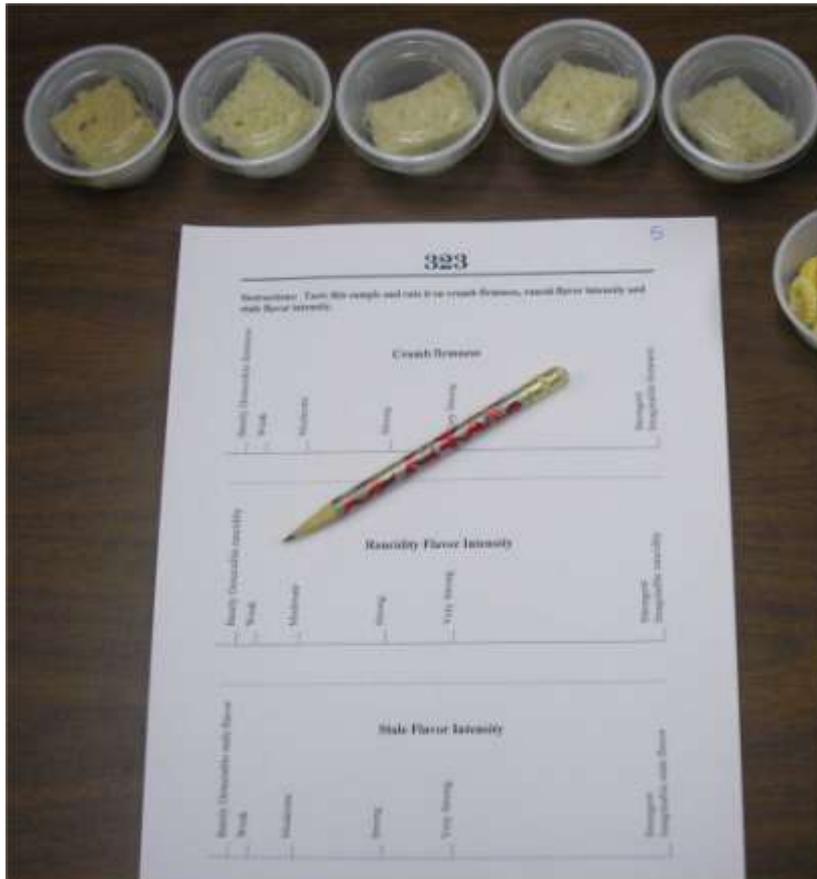
- **Does flaxseed impact processing conditions?**
  - ✓ **Will flaxseed alter product formulation requirements?**
  - ✓ **Will flaxseed require a change in processing parameters?**



# Flaxseed in Foods - General Approach



- **Methods - Sensory**



<b>0</b>	<b>Not detectable</b>
<b>1.31</b>	<b>Barely detectable</b>
<b>2.08</b>	<b>Very little</b>
<b>3.7</b>	<b>Moderate</b>
<b>6.95</b>	<b>Strong</b>
<b>9.5</b>	<b>Very strong</b>
<b>16.6</b>	<b>Strongest imaginable</b>



# Flaxseed in Cereal Products



- Bread – Application level



0%

5%

10%

15%

20%

**30 Mesh Flaxseed Level**



# Flaxseed in Cereal Products



- Bread – flaxseed particles



**14-20**



**20-30**



**40-60**

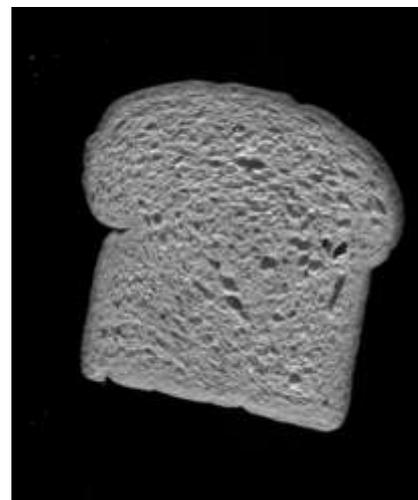


# Flaxseed in Cereal Products





# Flaxseed in Cereal Products



**Control**

**20 mesh**

**30 mesh**

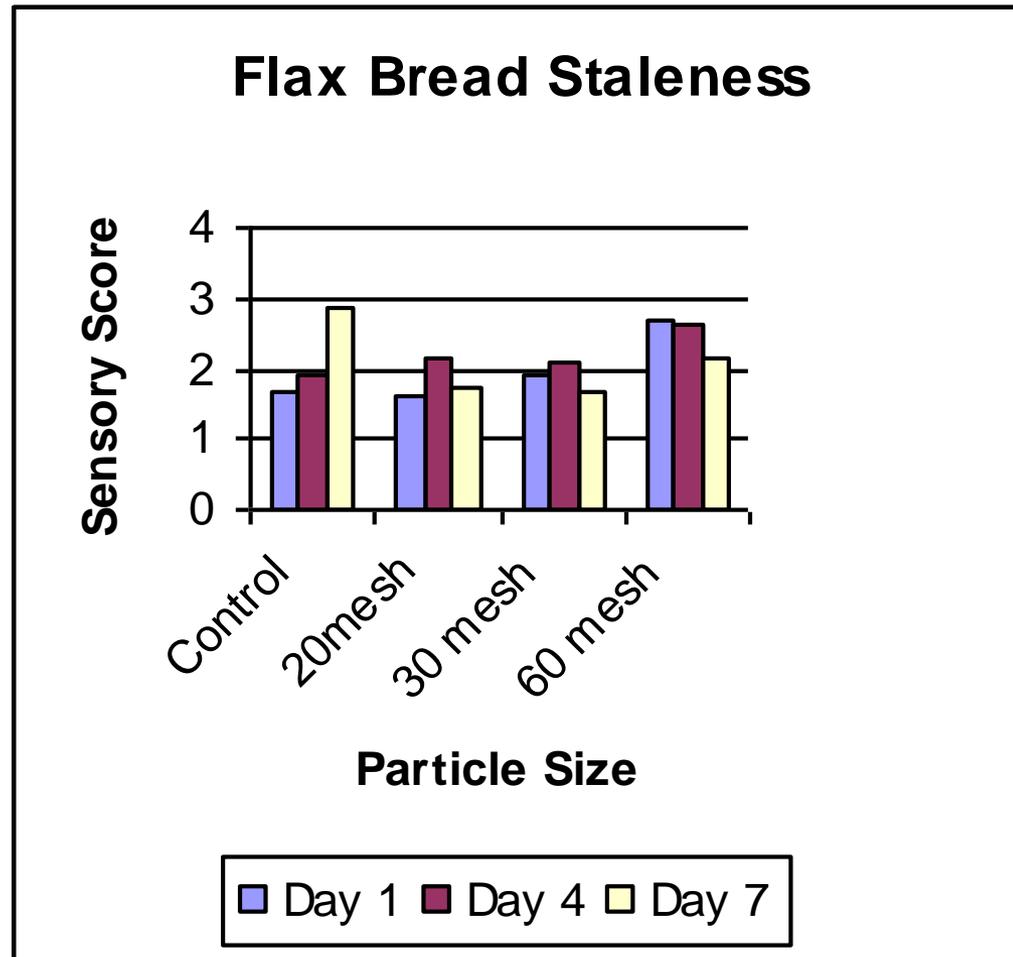
**60 mesh**



# Flaxseed in Cereal Products



- Bread – quality

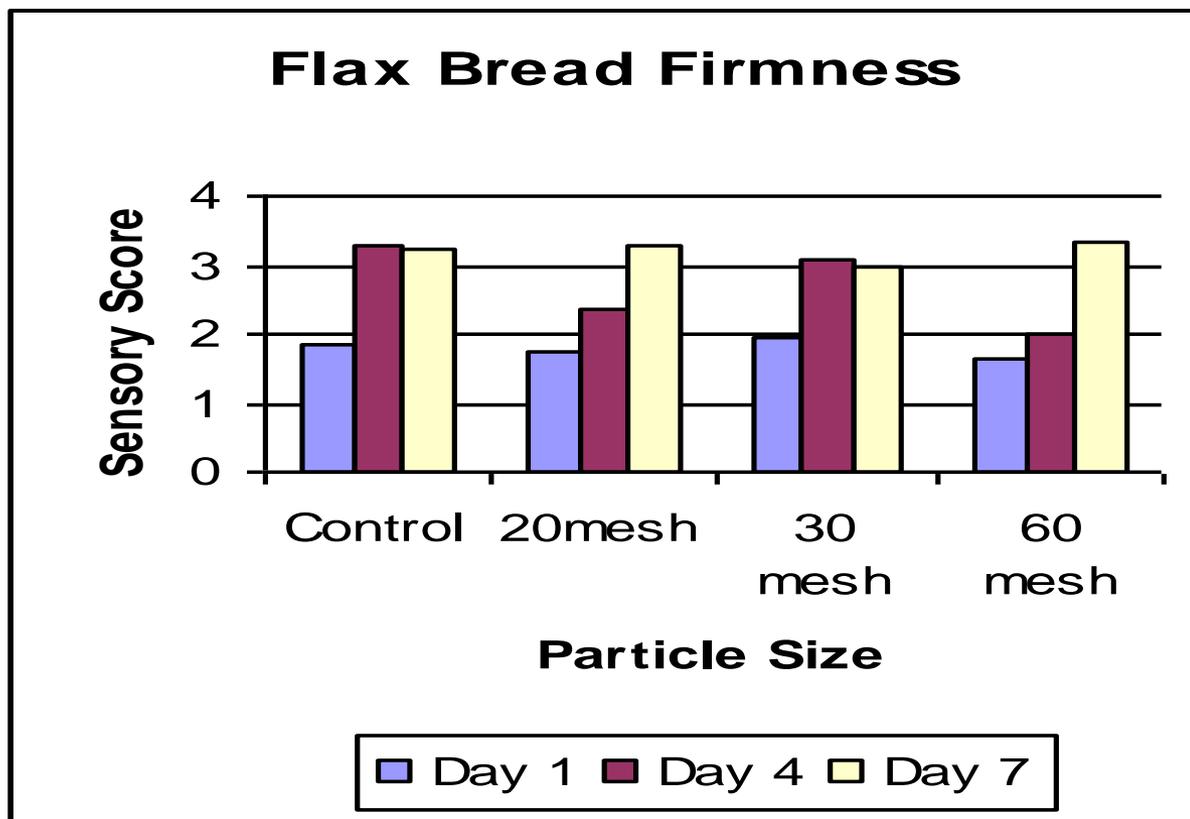




# Flaxseed in Cereal Products



- Bread – quality





# Flaxseed in Cereal Products



- **Visual Attributes - Pasta**





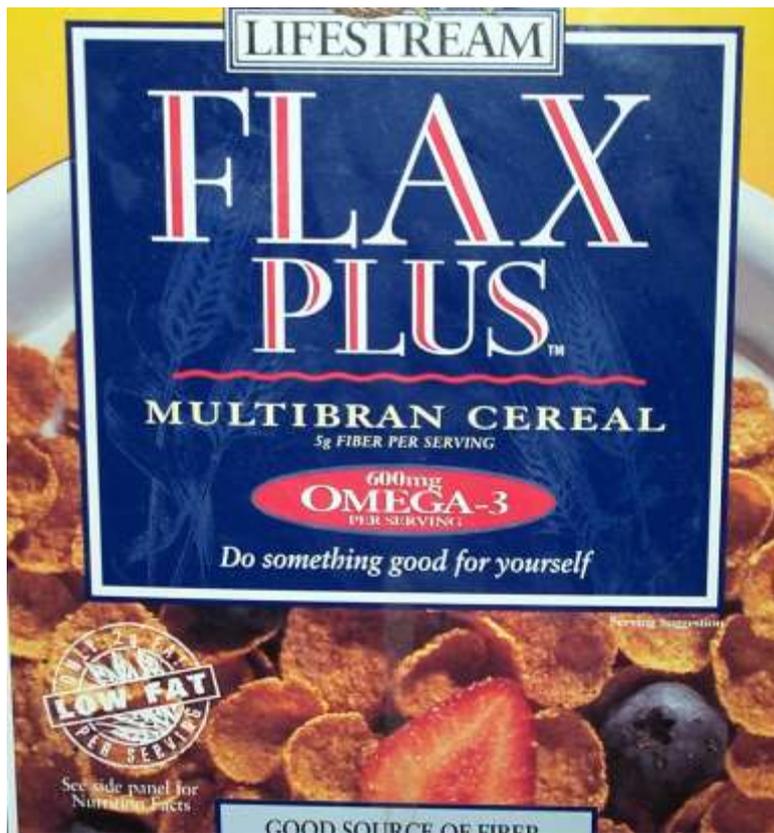
# Flaxseed in Pasta



- **Summary**
  - ✓ **No significant increase in oxidation in pasta fortified with Ground Whole Flaxseed**
  - ✓ **Fortification with flaxseed hull or steamed flaxseed reduced oxidative stability**



# Flaxseed in Breakfast Cereals





# Flaxseed in Dairy (Yogurt)



- **Rationale**

- ✓ **Limited information is available regarding the feasibility of supplementing yogurt with flaxseed oil.**



- **Treatments**

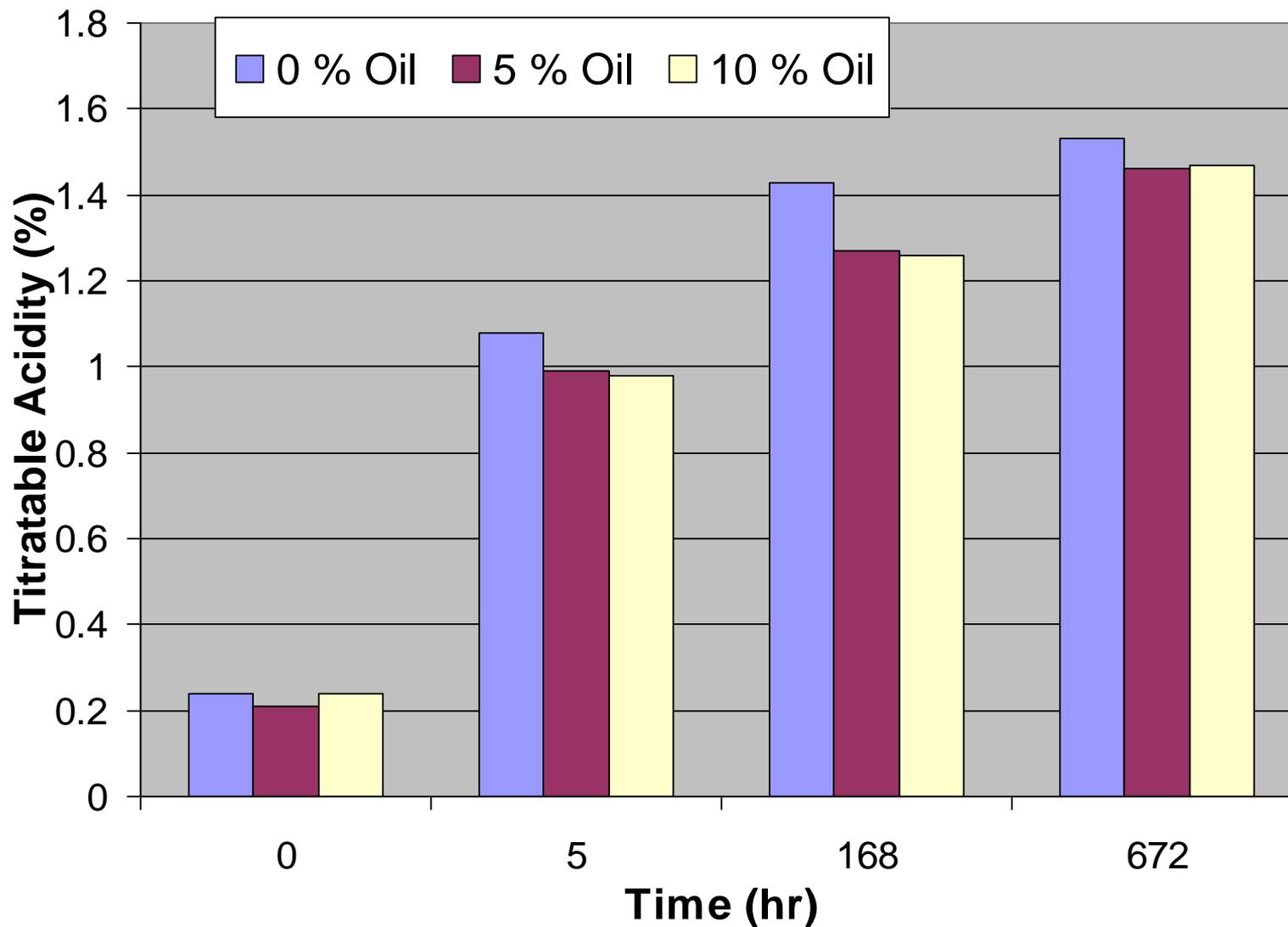
- ✓ **Milk (lowfat)**

- ✓ **Flaxseed oil (0, 5, 10 % - study 1)**

- ✓ **Flaxseed oil (0, 2.5, 5 % - study 2)**

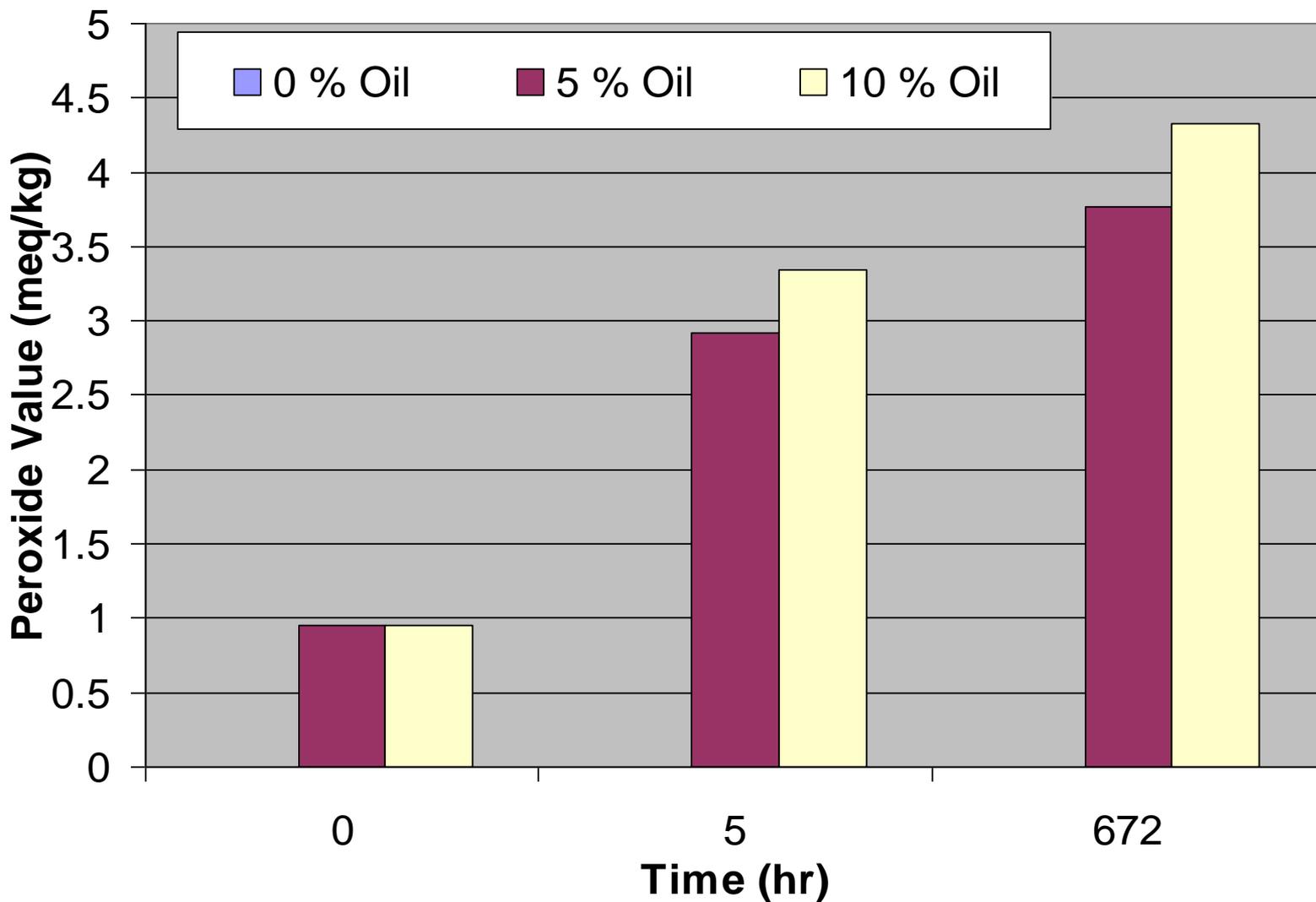


# Results - Study 1





# Results - Study 1

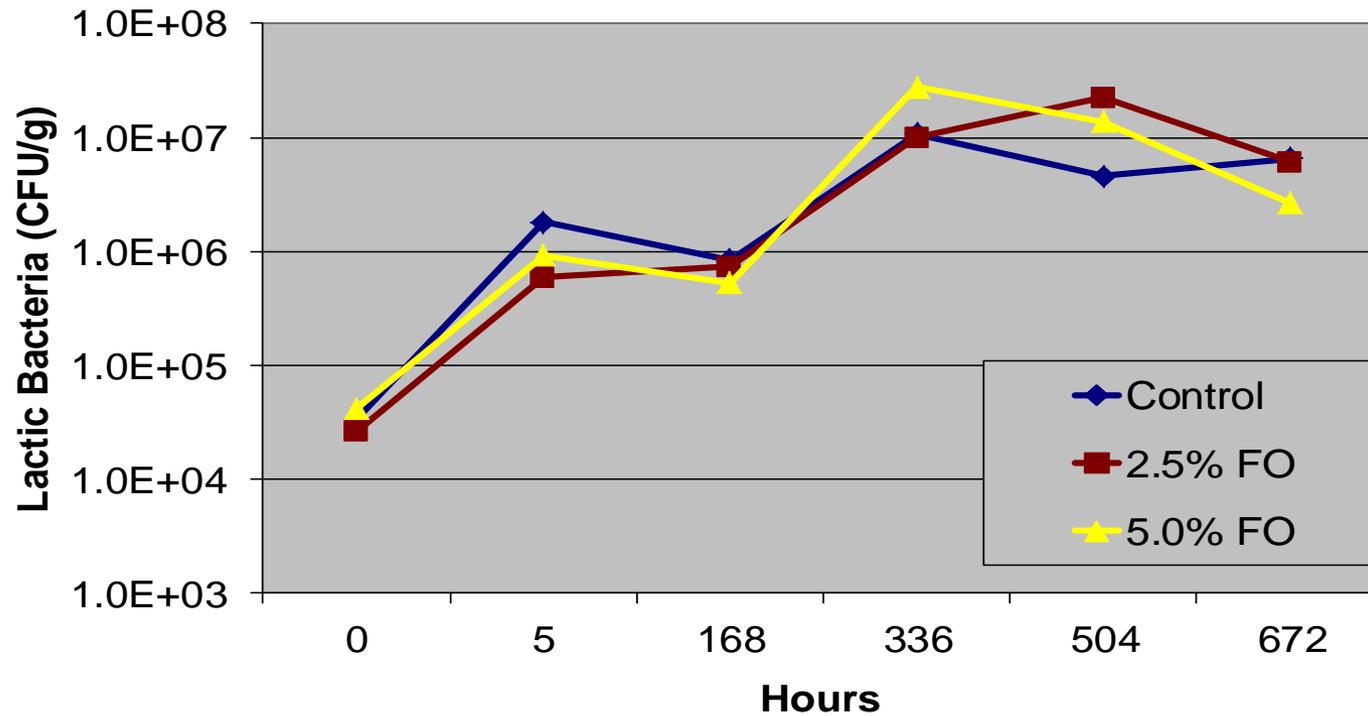




# Results - Study 2



**Lactic Acid Bacteria Count in yogurts with and without flaxseed oil fortification.**

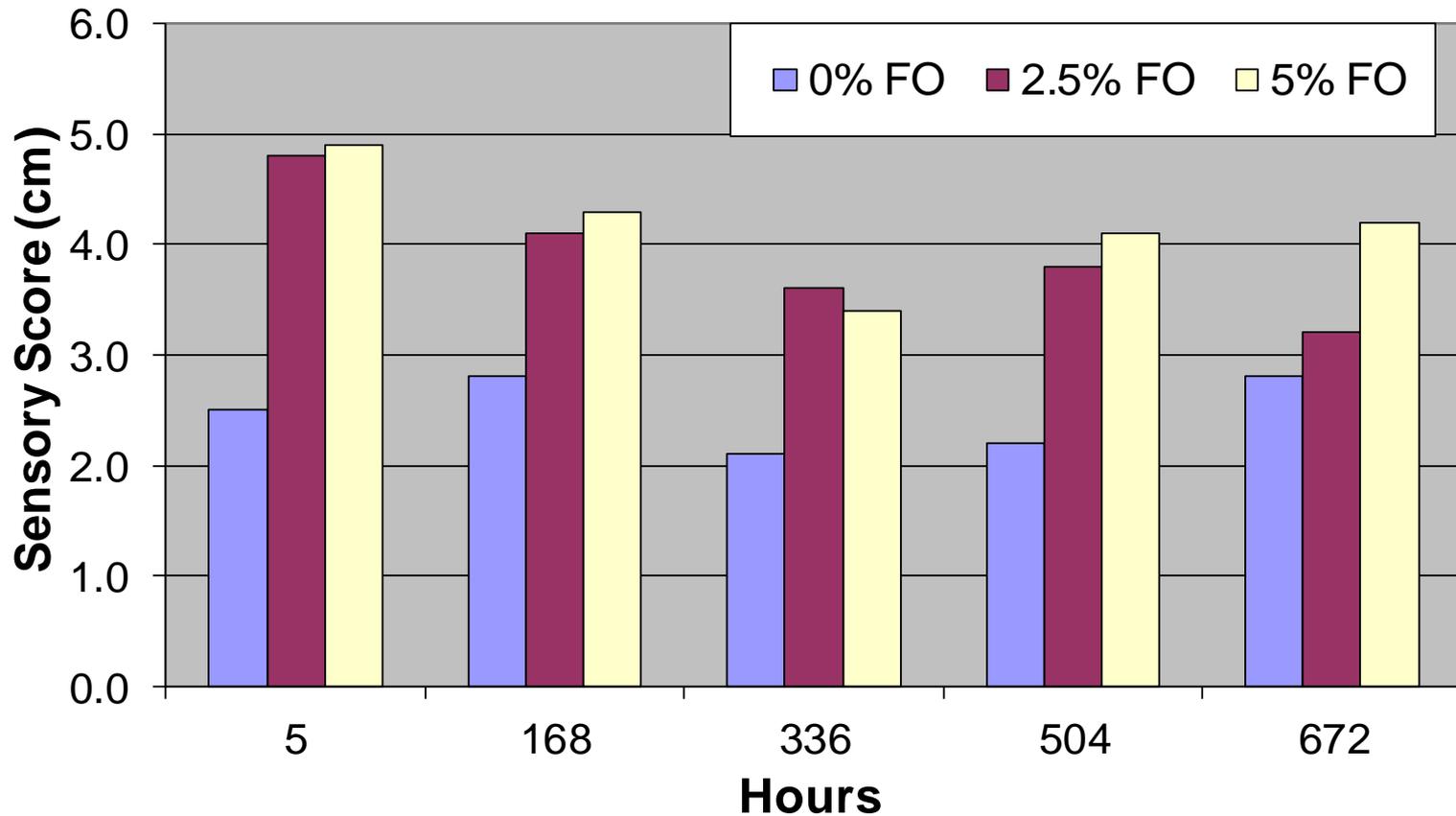




# Results - Study 2



**Sensory scores of yogurt with and without flaxseed oil fortification.**





# Conclusion



- 
- **Flaxseed oil (FO) addition up to 10% did not significantly affect yogurt production.**
  - **The higher PV & volatiles in FO yogurt did cause significant lower sensory score initially. However, the difference between the control and FO fortified diminished during storage.**



# Flaxseed in Yogurt - Lignan



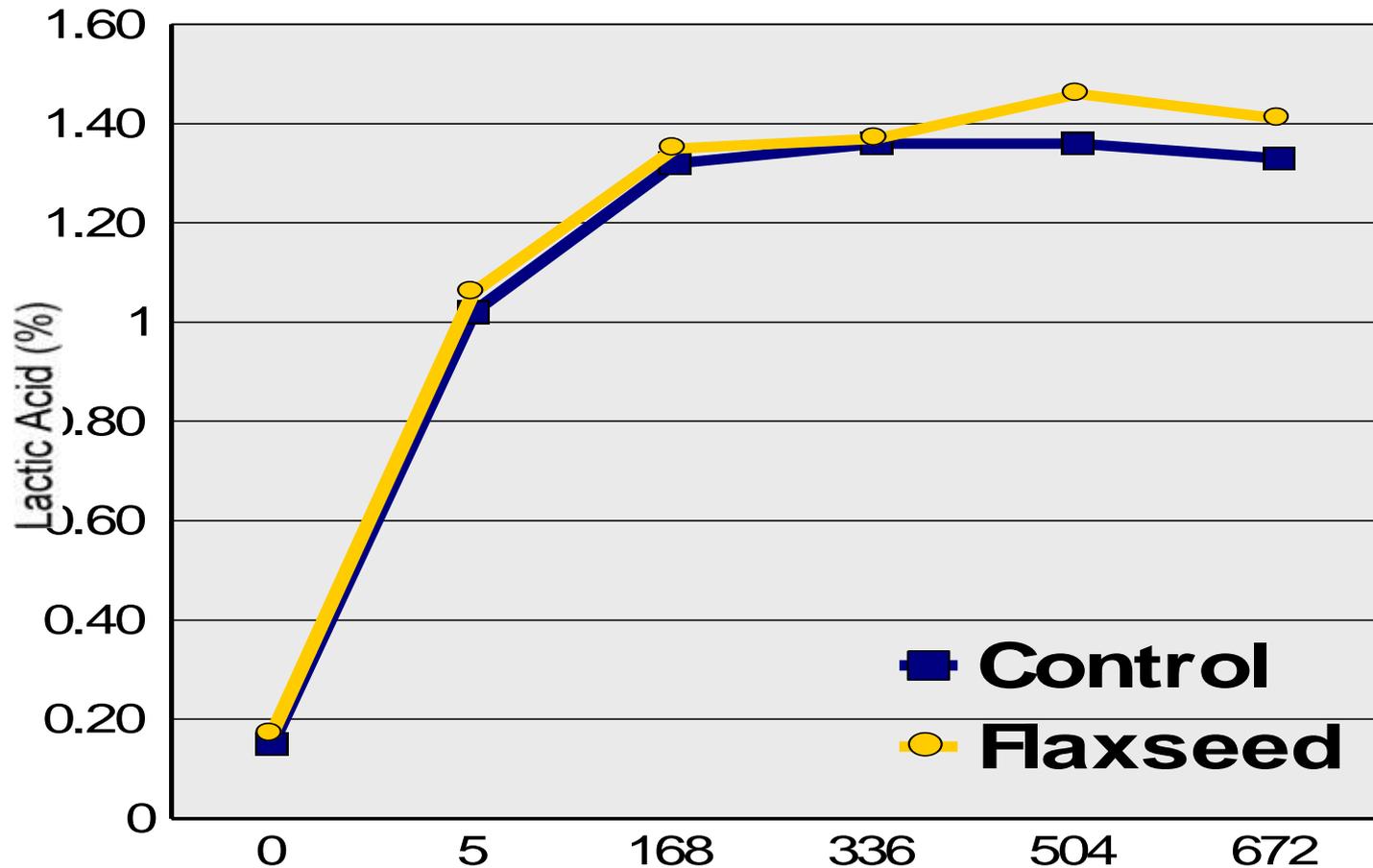
- **Rationale for incorporating flaxseed into yogurt**
  - ✓ **Incorporating a specific parts of flaxseed (e.g., SDG) into yogurt could provide humans with an alternative to consuming whole flaxseed.**



# Results



## Lactic Acid (%) Content in Yogurt Fortified With (700 ppm) or Without Flaxseed Extract

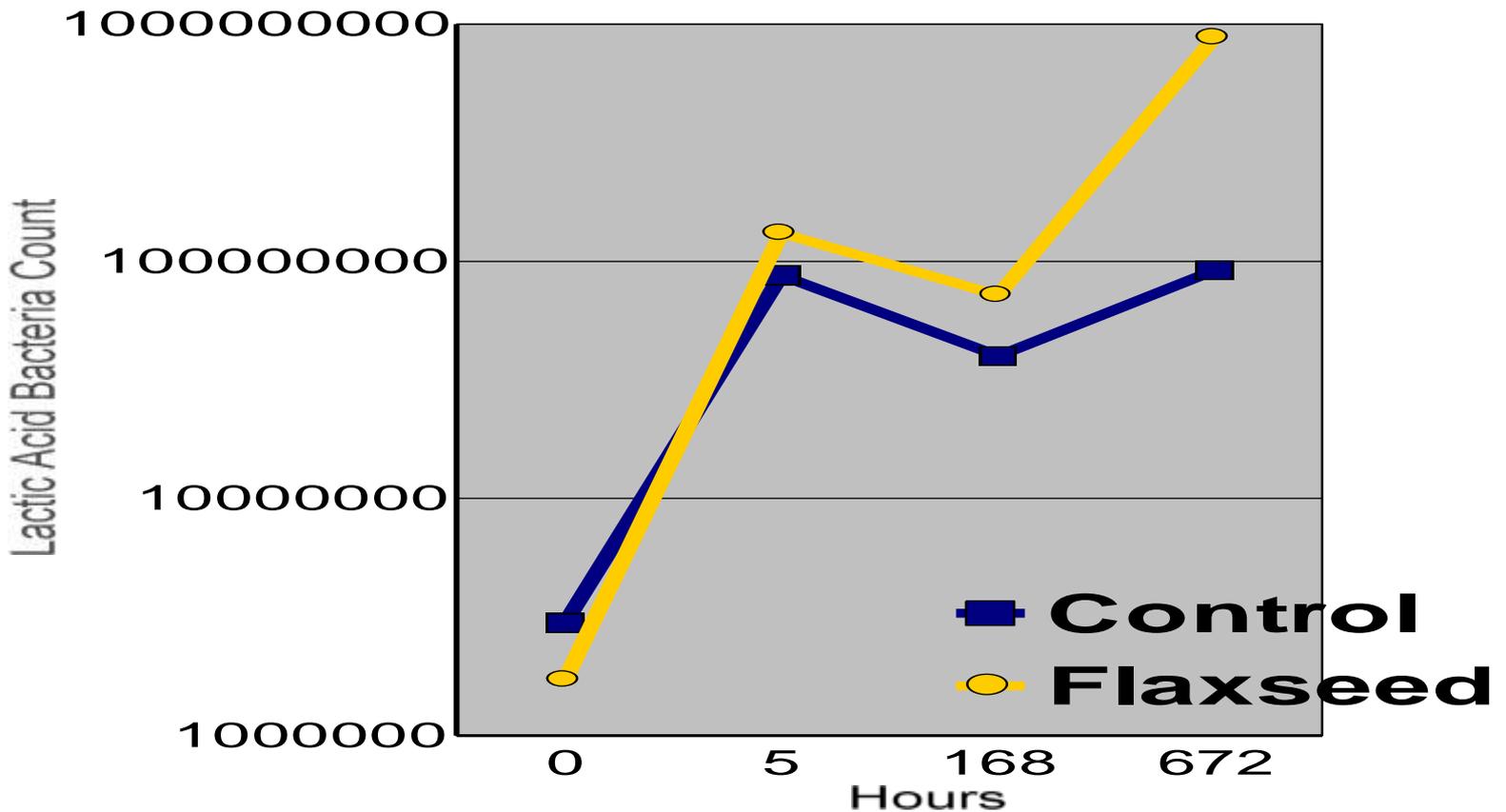




# Results



## Lactic Acid Bacteria (cfu) Content in Yogurt Fortified With (7000 ppm) or Without Flaxseed Extract.





# Information Gained from Experiment

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- The fermentation was not affected by lignan extract addition
- The lignan content was not affected by fermentation.



# Flaxseed in Frozen Desserts

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# Flaxseed in Frozen Desserts

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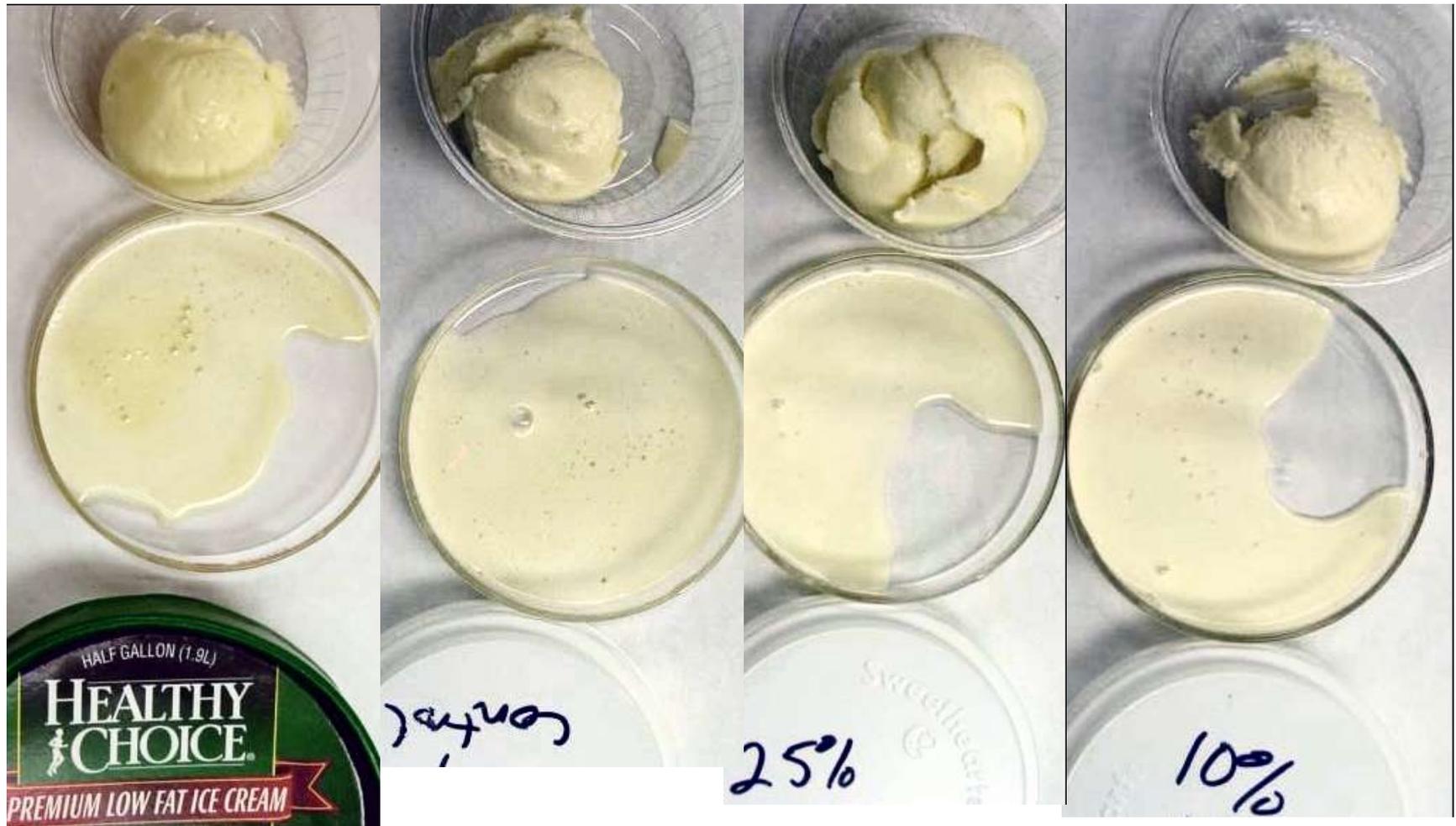
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- **Sensory Attributes**
  - ✓ Resembled a low fat ice cream
  - ✓ 60 % could not detect flaxseed oil



# Flaxseed in Frozen Desserts

- **Melt Characteristics**





# Roasted Flaxseed Studies

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- **Raw flaxseed**
  - ✓ **Nutty flavor**
  - ✓ **Sticky mouthfeel**
  - ✓ **Earthy and grassy aroma and flavor**



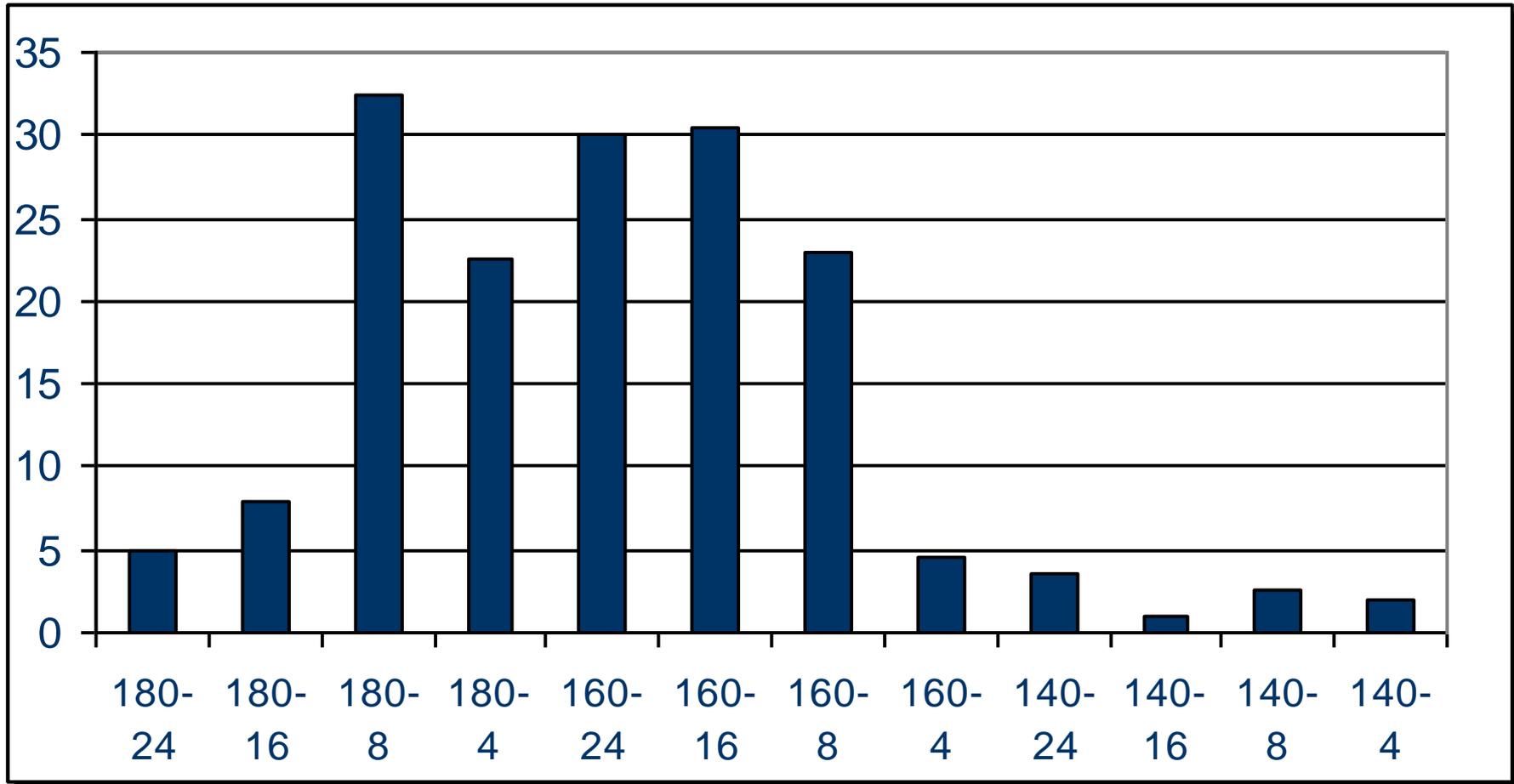
# Roasting in Oilseed Processing



- **Dry heat process helps to:**
  - ✓ **Extend shelf life**
  - ✓ **Enhance flavor and aroma**
  - ✓ **Inhibit enzymatic activity**



# Preliminary Studies in Flaxseed Roasting - Preference Test





# Roasted Flaxseed - Objectives

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- **To determine oxidative stability and shelf life of flaxseed.**
- **To identify volatiles in roasted flaxseed.**



# Roasted Flaxseed



- **Screened Roasted Flaxseed Samples**
  - ✓ **Control**
  - ✓ **160°C 16 min**
  - ✓ **160°C 24 min**
  - ✓ **180°C 8 min**
- **Storage**
  - ✓ **0, 2, 4, 6 and 8 week**
  - ✓ **25 and 30°C (Accelerated)**



# Roasted Flaxseed



- **Summary**

- ✓ Peroxide values increased with storage time.
- ✓ Propanal, hexanal, and cis-3-hexenal contents increased with storage time.
- ✓ Propanal, hexanal and cis-3-hexenal were observed in lower concentrations in vacuumed packed samples.



# Roasted Flaxseed



- **Conclusion**
  - ✓ **Roasting significantly decreased water activity.**
  - ✓ **Increases in peroxide values, propanal and hexanal contents with storage time indicate a decrease in stability of roasted flaxseed over time.**
  - ✓ **Vacuum packaging significantly improves the oxidative stability of roasted flaxseed.**



# Extruded Bean-Flaxseed Snacks



**Navy-Control**

**5% F**

**10%F**

**15%F**

**20%F**



**Pinto -Control**

**5% F**

**10%F**

**15%F**

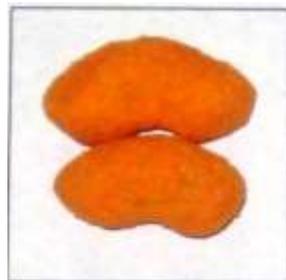
**20%F**



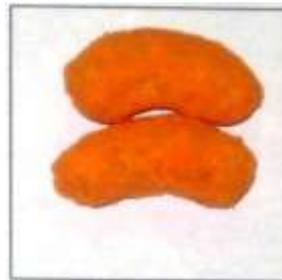
# Extruded Bean-Flaxseed Snacks



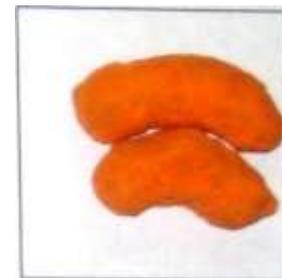
**Corn Control**



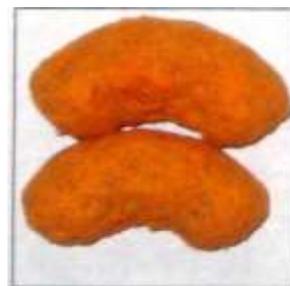
**Navy Control**



**Navy 5%  
Flax**



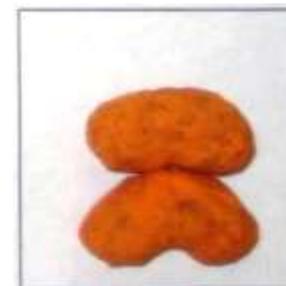
**Navy 10%Flax**



**Pinto Control**



**Pinto 5% Flax**



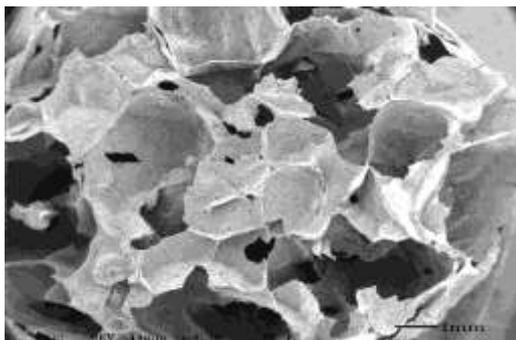
**Pinto 10% Flax**



# Extruded Bean-Flaxseed Snacks

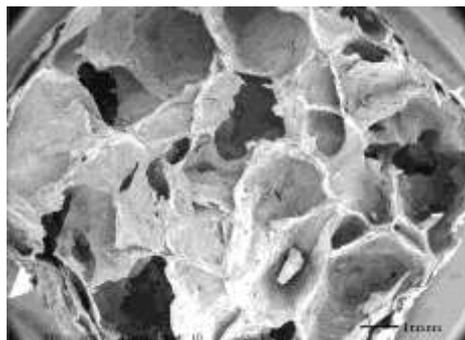


### Navy-Corn Control



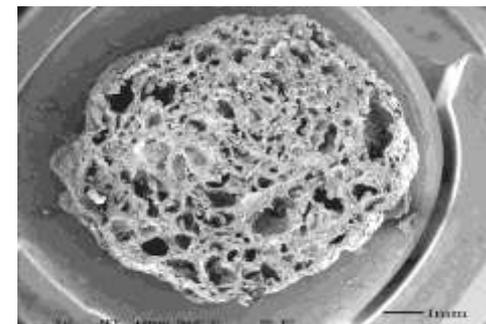
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Comment: ANC (0)  
Date: 01-28-2007 Time: 14:03  
Filename: I5065.TIF

### Navy-Corn 10% Flaxseed



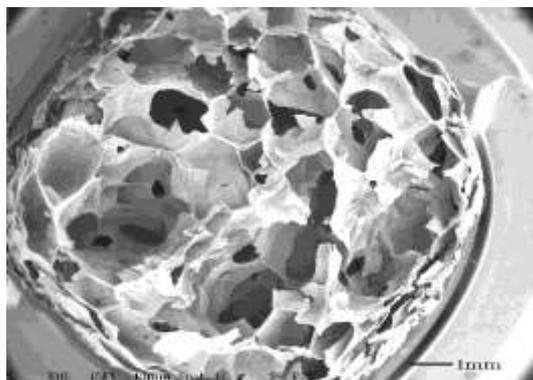
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Date: 01-28-2007 Time: 02:43  
Filename: I5065.TIF

### Navy-Corn 20% Flaxseed



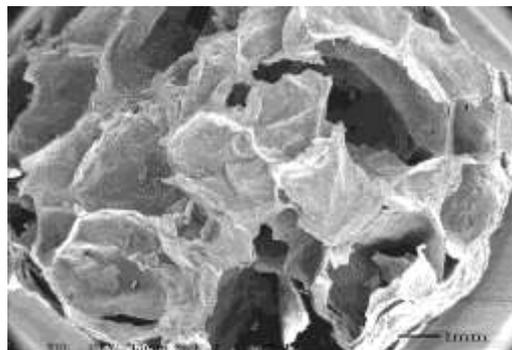
Title: I50330  
Comment: INC (0)  
Date: 01-29-2007 Time: 10:04  
Filename: I5064.TIF

### Pinto - Corn Control



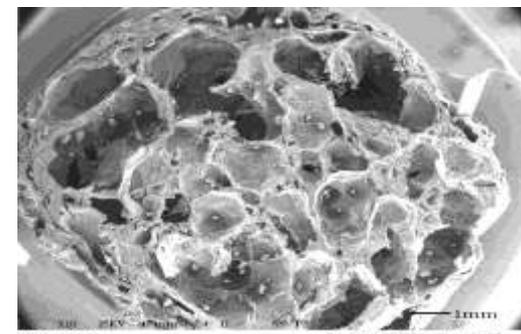
Title: I503105  
Comment: APC (0)  
Date: 01-29-2007 Time: 13:30  
Filename: I3665.TIF

### Pinto -Corn 10% Flaxseed



Title: I503105  
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Date: 01-29-2007 Time: 12:04  
Filename: I3665.TIF

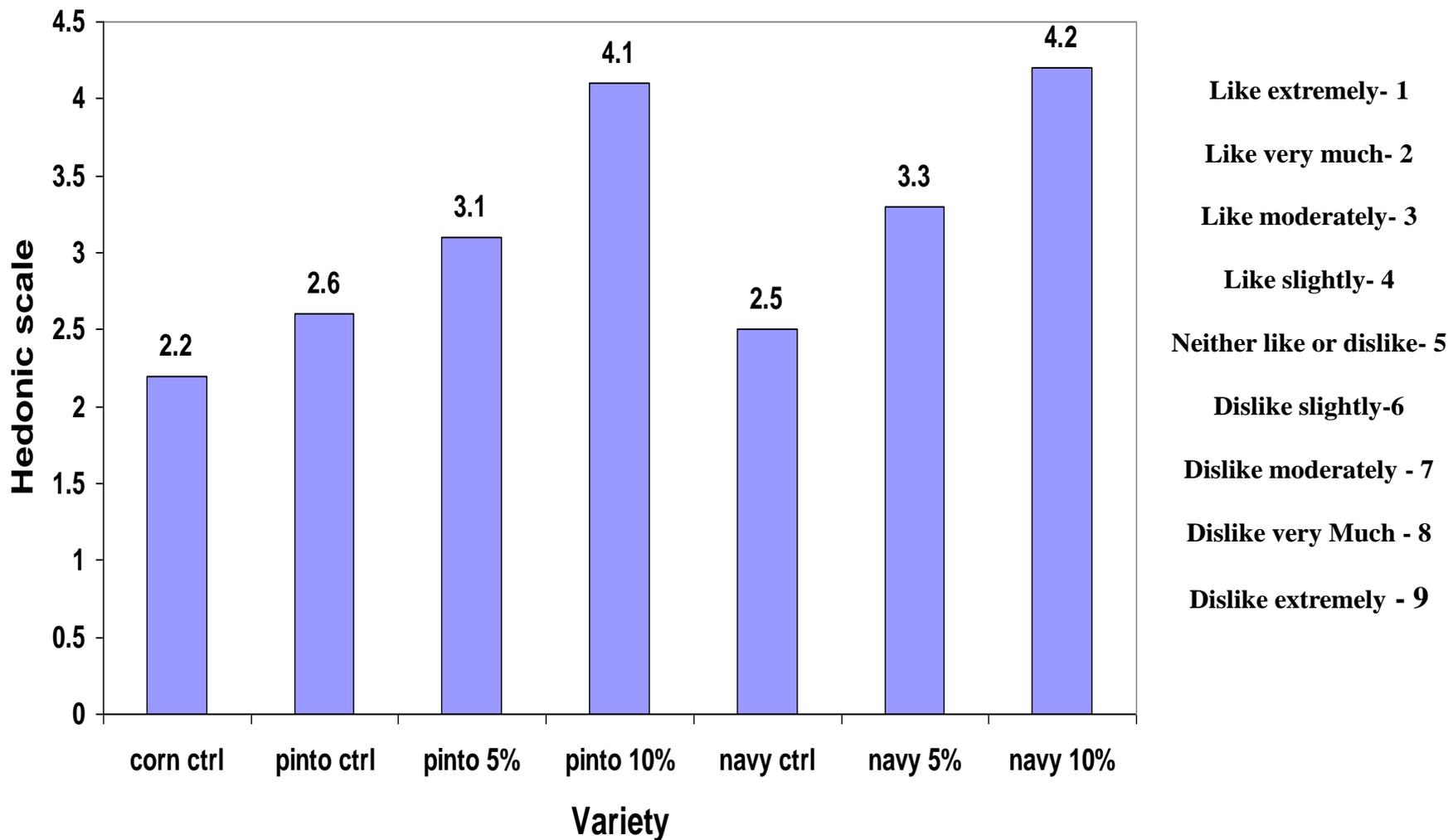
### Pinto -Corn 20% Flaxseed



Title: I503105  
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Date: 01-29-2007 Time: 12:04  
Filename: I3665.TIF

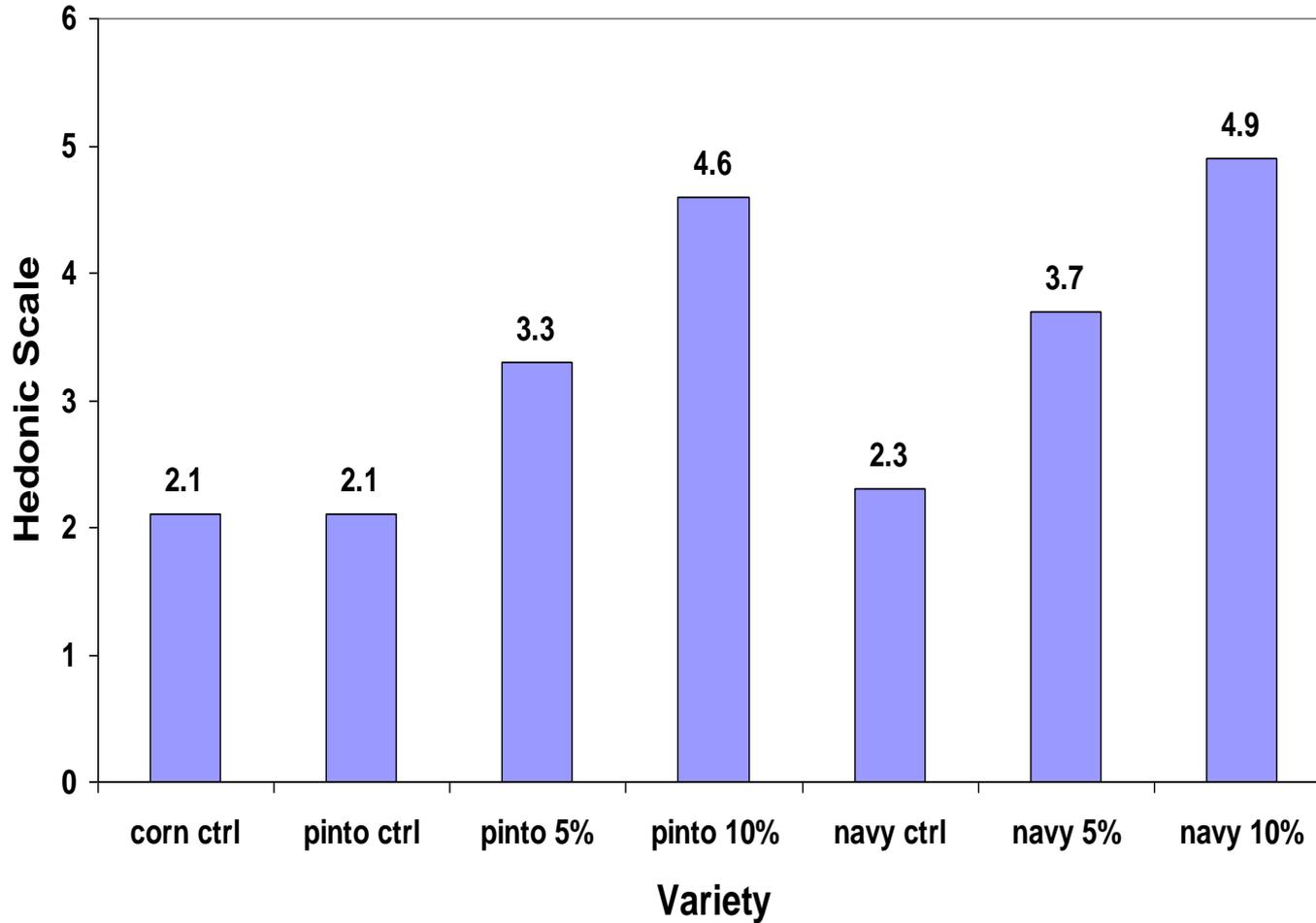


# Extruded Bean-Flaxseed Snacks Acceptability





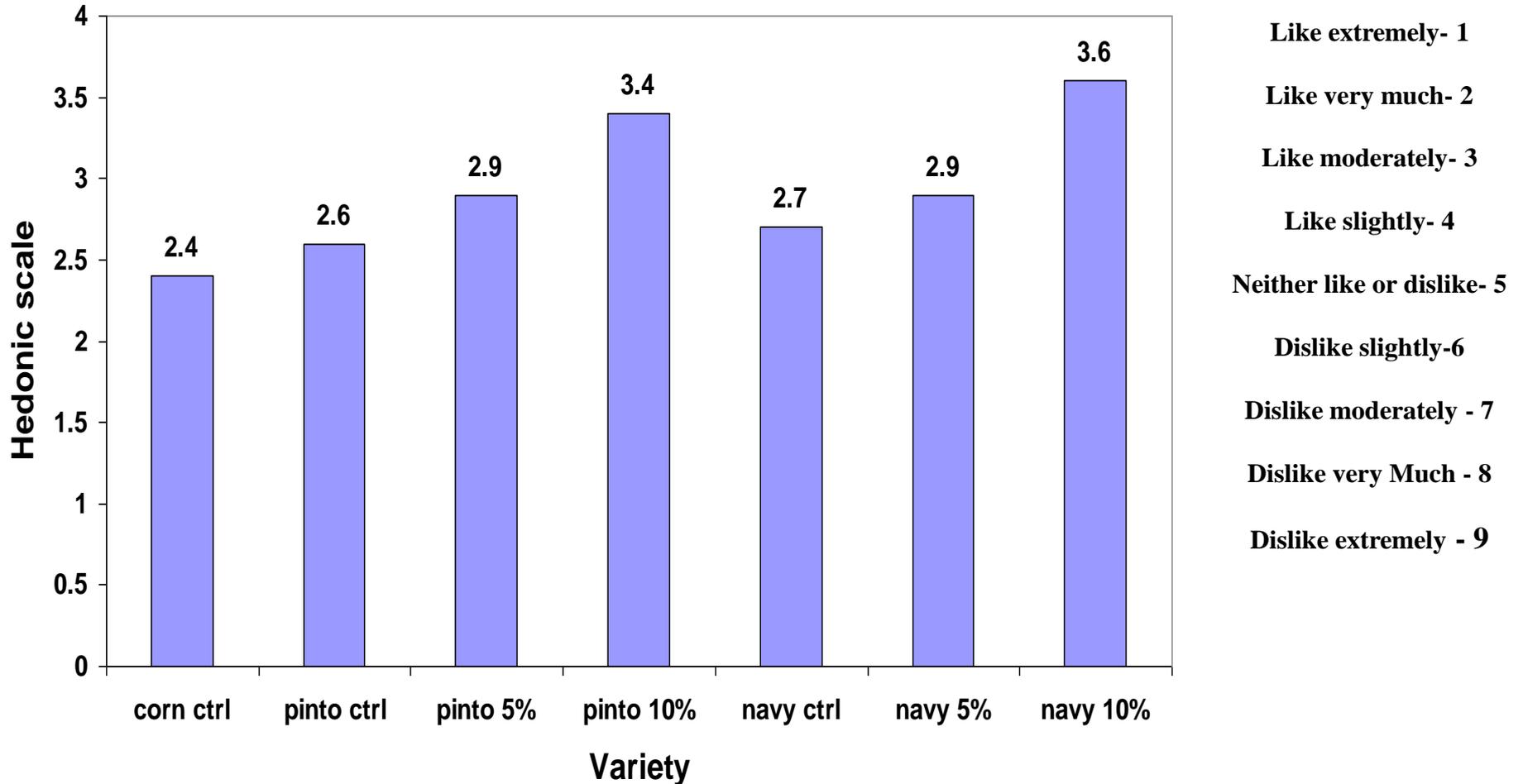
# Extruded Bean-Flaxseed Snacks Texture



- Like extremely- 1
- Like very much- 2
- Like moderately- 3
- Like slightly- 4
- Neither like or dislike- 5
- Dislike slightly-6
- Dislike moderately - 7
- Dislike very Much - 8
- Dislike extremely - 9



# Extruded Bean-Flaxseed Snacks Flavor





# Commercial products with flaxseed ingredients



Bread with golden flax



Gluten free bar



Potato chip



multigrain wrap



soup with flax flour



granola



chocolate bar



yogurt



# Thank you & Questions?



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