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Potential Use of Flaxseed in Egg Production

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The authors accept responsibility for any omissions or errors.

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Highlights

Flaxseed contains omega-3 fatty acids, which appear to benefit the cardiovascular system by reducing low-density lipids, cholesterol, and blood platelet stickiness. Egg yolk lipids can be influenced through dietary fat, and omega-3 fatty acids can be enriched through addition of flaxseed to diets of laying hens. Data from research in Canada indicate a benefit to people consuming "flax eggs," that is, the people consuming several eggs/week had no increase or some decrease of LDL cholesterol and triglycerides in their blood. These findings could improve the image of eggs to the health-conscious public.

This report presents an overview of the U. S. egg industry, egg production and use. It also examines research on use of flaxseed as a feed ingredient, presence of omega-3 fatty acids in the eggs, and profitability of using flaxseed in laying hen rations. Increased acreage of flax necessary to meet increased demand was also estimated.

Adoption of flaxseed into poultry rations for laying hens would increase demand of flaxseed. To meet this demand, at 20 percent adoption, 556,039 to 1,112,078 acres of flax would be needed for 8 to 16 percent flaxseed in poultry rations at 15.1 bu/acre. If 10 percent of the producers adopted the flaxseed rations, 278,139 to 556,039 acres (8 and 16 percent adoption) would be needed to meet the demand. A competitive price for flaxseed was determined for flax to be considered as a substitute for non-program hard red spring wheat in North Central and Northeastern North Dakota.

In 1992, North Dakota produced 2.73 million bushels of flax, 83 percent of the U. S. production. An increase in demand for flaxseed could benefit North Dakota flaxseed producers and the entire flaxseed industry.

Potential Use of Flaxseed in Egg Production

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Flaxseed contains omega-3 fatty acids, which appear to benefit the cardiovascular system by reducing low-density lipids, cholesterol, and blood platelet stickiness. Egg yolk lipids can be influenced through dietary fat, and omega-3 fatty acids can be enriched through addition of flaxseed to diets of laying hens (Jiang et al. 1990). The objective of this study was to investigate the potential for increasing the use of flaxseed as a feed ingredient in rations for egg-laying hens.

North Dakota and U.S. flaxseed production, yields and prices; imports, exports, and flaxseed use; and, use in the baking industry is discussed in *The Potential for Flaxseed Utilization in the U.S. Baking Industry* (Holstun et al. 1993). A competitive price for flaxseed as a substitute for non-program hard red spring wheat in North Central and Northeastern North Dakota was also determined.

This report presents an overview of the U. S. egg industry, egg production and use. It also examines research on use of flaxseed as a feed ingredient, presence of omega-3 fatty acids in the eggs, and profitability of using flaxseed in laying hen rations. Increased acreage of flax necessary to meet increased demand was also estimated. In 1992, North Dakota produced 2.73 million bushels of flax, 83 percent of the U. S. production (North Dakota Agricultural Statistics Service 1993). An increase in demand for flaxseed could benefit North Dakota flaxseed producers and the entire flaxseed industry.

The Egg Industry

The U.S. poultry industry started as a home industry. Since World War II, better management and breeding programs, with development of commercial flocks for egg and broiler production brought rapid growth to the poultry industry. Changes in location occurred during this period (Patrick and Schaible 1989). The egg industry in the United States was historically a Corn Belt industry. However, the West Coast and Southeastern states have become major production areas (Stadelman 1990). The concentration of laying hens and pullets in the United States by state and the distribution of laying hens and pullets in the U.S. by region in 1992 are shown in Figure 1. California had the largest population in 1992, with 26,650,000 laying hens; followed by Pennsylvania with 20,668,000; Indiana, 20,257,000; Ohio, 18,443,000; Georgia, 18,117,000; and Arkansas, 15,246,000. The Southeastern states reported large populations of laying hens, as did Texas, Iowa, and Minnesota (Agricultural Statistics Board 1992). Changes in number of laying hens and pullets by regions for 1965 to 1990 are shown in Figure 2.

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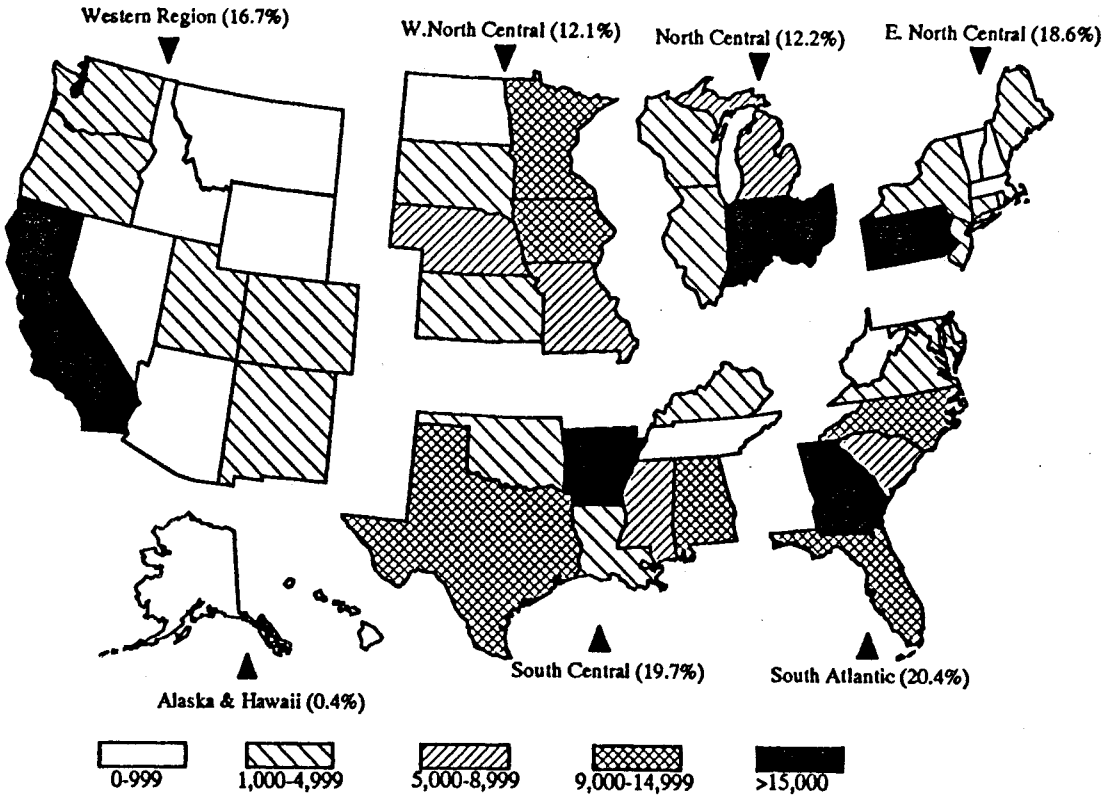

Figure 1. Concentration of Laying Hens and Pullets by State and Population by Region, United States, 1992.
Source: Agricultural Statistics Board, 1992, *Eggs, Chickens, and Turkeys.*

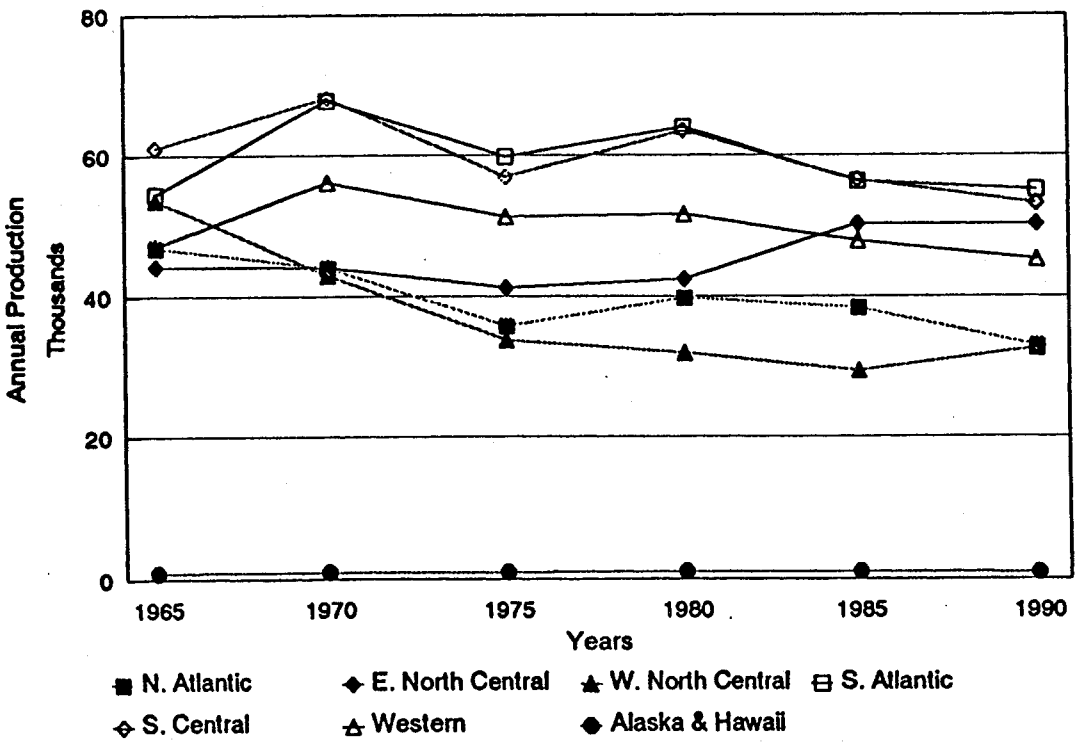

Figure 2. U.S. Laying Hens and Pullets, by Region, 1965-1990.
Source: Adapted from Appendix Table 1.

Egg production within regions in the United States has changed since 1965. Production in the West North Central region declined from 17.5 percent of U.S. production in 1965 to 10 percent in 1985, but returned to 14.4 percent in 1992 (Table 1). The South Atlantic and South Central regions showed increases in egg production from 1965 to 1985. However, this trend has changed again with more uniform production across regions. The largest variation in production has not taken place by region, but across states within regions. Regional changes in egg production in the United States are shown in Figure 3.

Table 1. U.S. Egg Production by State and Region, 1965-1992

State	1965	1970	1975	1980	1985	1990	1992
	million eggs						
Connecticut	747	927	817	1,004	1,173	1,029	940
Massachusetts	553	521	537	326	257	235	213
Maine	944	1,462	1,650	1,793	1,237	1,069	1,078
New Hampshire	332	300	283	182	121	43	63
New Jersey	1,498	779	620	279	474	442	515
New York	2,029	2,297	1,984	1,776	1,710	975	1,040
Pennsylvania	3,238	3,328	3,299	4,251	4,774	4,976	5,513
Rhode Island	80	77	70	84	80	53	57
Vermont	144	129	105	100	67	31	31
N. ATLANTIC	9,565	9,820	9,365	9,795	9,893	8,853	9,450
Production share	14.8%	14.0%	14.5%	14.1%	14.5%	13.0%	13.4%
Illinois	1,776	1,905	1,483	1,267	732	793	801
Indiana	2,240	2,880	2,609	3,697	5,538	5,445	5,207
Michigan	1,372	1,417	1,303	1,459	1,693	1,406	1,398
Ohio	2,308	2,071	1,999	2,333	3,592	4,667	5,021
Wisconsin	1,585	1,216	1,194	946	836	910	831
N. CENTRAL	9,281	9,489	8,588	9,702	12,391	13,221	13,258
Production share	14.4%	13.5%	13.3%	13.9%	18.1%	19.5%	18.8%
Iowa	3,610	3,034	2,006	1,784	1,600	2,151	2,902
Kansas	935	842	599	427	472	404	355
Minnesota	2,494	2,247	2,209	2,223	2,267	2,499	2,805
Missouri	1,289	1,469	1,241	1,460	1,351	1,580	1,575
Nebraska	1,283	1,071	782	847	844	1,202	1,777
North Dakota	342	218	132	82	118	51	41
South Dakota	1,321	1,053	701	464	391	435	690
W. N. CENTRAL	11,274	9,934	7,670	7,287	7,043	8,322	10,145
Production share	17.5%	14.1%	11.9%	10.5%	10.3%	12.3%	14.4%
Alaska	9	5	5	4	12	1	1
Hawaii	188	197	209	222	221	228	222
ALASKA & HAWAII	197	202	214	226	232	229	223
Production share	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%

- Continued -

Table 1 (Continued)

State	1965	1970	1975	1980	1985	1990	1992
Delaware	125	126	115	138	126	168	164
Florida	1,599	2,547	2,779	3,004	2,692	2,586	2,341
Georgia	3,546	5,396	5,284	5,637	4,282	4,302	4,326
Maryland	268	330	331	381	813	885	855
North Carolina	2,396	3,671	2,802	3,174	3,294	3,045	3,026
South Carolina	1,119	1,296	1,384	1,679	1,573	1,422	1,447
Virginia	1,215	1,092	765	913	850	943	1,008
West Virginia	320	319	256	149	121	136	180
S. ATLANTIC	10,588	14,777	13,716	15,075	13,751	13,487	13,347
Production share	16.4%	21.0%	21.3%	21.6%	20.1%	19.9%	18.9%
Alabama	2,248	2,720	2,951	3,354	2,794	2,206	2,512
Arkansas	2,362	3,482	3,594	4,153	3,655	3,620	3,601
Kentucky	1,000	659	518	536	431	412	578
Louisiana	604	769	658	553	348	273	316
Mississippi	2,444	2,470	1,707	1,584	1,251	1,434	1,408
Oklahoma	484	569	430	839	868	869	873
Tennessee	982	1,264	949	962	756	277	262
Texas	2,548	2,679	2,360	3,092	3,131	3,317	3,462
S. CENTRAL	12,672	14,612	13,167	15,073	13,234	12,408	13,012
Production share	19.6%	20.8%	20.4%	21.6%	19.3%	18.3%	18.4%
Arizona	193	224	159	113	99	73	85
California	8,016	8,380	8,467	8,796	8,052	7,472	7,007
Colorado	272	335	473	464	568	788	837
Idaho	265	189	184	202	239	187	214
Montana	188	240	196	170	202	172	160
Nevada	9	4	4	2	2	2	2
New Mexico	151	224	234	378	273	283	303
Oregon	534	533	519	638	649	652	686
Utah	249	263	321	416	418	456	493
Washington	1,076	1,046	1,084	1,295	1,355	1,287	1,305
Wyoming	58	40	30	11	7	2	2
WESTERN	11,011	11,478	11,671	12,484	11,864	11,374	11,094
Production share	17.0%	16.3%	18.1%	17.9%	17.3%	16.8%	15.7%
UNITED STATES	64,588	70,312	64,391	69,686	68,645	67,832	70,528

Source: *Livestock and Poultry Situation and Outlook*, USDA, various issues.
Agricultural Statistics, USDA, various issues.

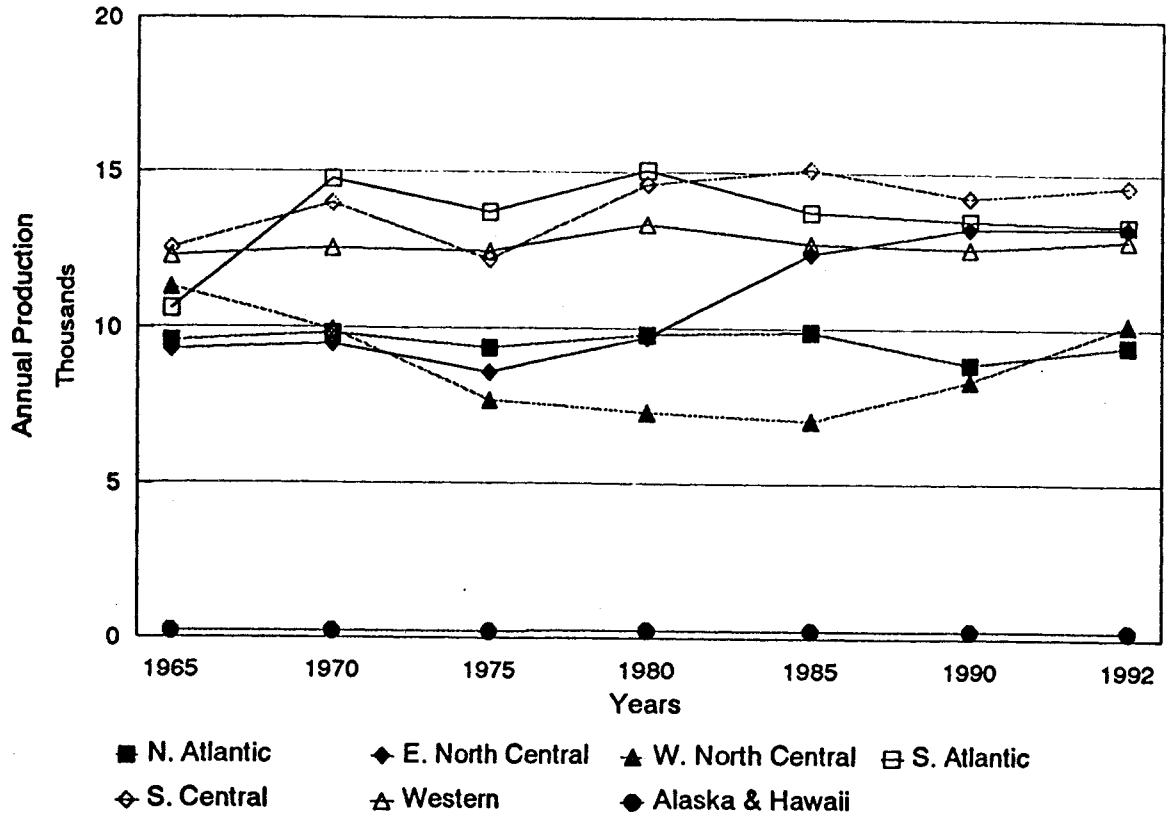

Figure 3. U.S. Egg Production by Region, 1965-1992.
Source: Adapted from Table 1 and Appendix Table 2.

The egg-breaking industry had historically been concentrated in the North Central and Western Plains states. These plants have gradually shifted operations to the West Coast and the Southeast following the relocation of egg production to these areas (Stadelman 1990).

The poultry industry has become more efficient in egg production, meat production, and labor management. Egg production has improved from 122 eggs/hen/year in 1925 to 235 in 1976 and 254 in 1992 (Table 2). But, as egg production has become more efficient, egg consumption has declined. Annual per capita consumption of eggs declined from 312 in 1963 to 274 in 1976 and 235 in 1992 (Patrick and Schaible 1989; USDA 1992). The decrease in egg consumption has been due chiefly to the change in eating habits and to the publicity given to the dietary effects of cholesterol.

Total production, imports, exports and per capita consumption are shown in Table 3. Total production has increased by 10 percent from 1976 to 1992, while the number of hens and pullets has remained the same. While per capita consumption has decreased, an increase in population has kept total consumption the same.

Table 2. Number of Laying Hens and Eggs Produced in the United States, 1976-1992

Year	Hens and Pullets	Rate of Lay/layer	Eggs: Total Production	Eggs: Consumption: Total	Eggs: Consumption: Per Capita
	thousands	number	millions	million	number
1976	274,135	235	64,511	59,172	274
1977	274,875	235	64,602	59,100	268
1978	281,544	239	67,157	60,732	273
1979	288,623	240	59,209	62,556	278
1980	287,705	242	69,686	62,028	272
1981	287,774	243	69,825	61,080	266
1982	286,369	243	69,718	61,656	266
1983	276,263	247	68,169	61,296	262
1984	277,960	245	68,222	61,812	262
1985	277,592	247	68,645	61,248	257
1986	279,046	248	69,106	61,344	255
1987	283,872	248	70,356	61,920	255
1988	277,781	251	69,665	60,492	247
1989	269,347	250	67,236	58,704	237
1990	269,679	252	67,832	58,728	235
1991	273,149	252	68,958	58,752	233
1992	277,819	254	70,528	60,698	235

Source: *Agricultural Statistics*, USDA, various issues.

The egg industry is divided into areas of specialization, as is true of most production industries. Few poultry breeders supply the hatching eggs for the commercial laying flocks. The number of hatcheries operating today is smaller than it was 20 years ago. The industry has specialists in feed formulation and manufacture, replacement pullet rearing, equipment and house construction, laying flock management, and egg marketing. Because capital requirements are high for a poultry enterprise and the per unit profit is small, fewer individual producers are willing to accept the financial risks associated with poultry production. As a result, the entire industry is becoming linked either directly or indirectly with other industries, such as feed, transportation, construction, and equipment manufacturers. Most integrated operations have separate facilities for each aspect of poultry production (Parkhurst and Mountney 1988). Prices producers received for all eggs and net returns per dozen eggs are shown in Table 4.

Eggs are usually marketed as shell eggs, although an increasing percentage of the total production is sold to the consumer as egg products or formulated eggs (Stadelman 1990). In 1991, approximately 25 percent of eggs were sold in a processed form (USDA 1992).

Table 3. Eggs, Total Production, Imports, Exports, Use, and Consumption, United States, 1970-1991

Year	Total Egg Production	Storage at Beginning of the Year	Imports	Exports	Eggs Used for Hatching	Storage at the End of the Year	Consumption Total	Consumption Per Capita
	million dozen	million dozen	million dozen	million dozen	million dozen	million dozen	million dozen	number
1970	5,704	34	27	45	402	39	5,201	309
1971	5,806	39	10	44	389	58	5,304	312
1972	5,742	58	1	56	391	53	5,237	304
1973	5,502	53	13	49	392	34	5,051	291
1974	5,461	34	13	57	366	42	5,005	286
1975	5,382	42	5	62	372	28	4,924	280
1976	5,377	28	3	65	409	21	4,868	274
1977	5,408	21	14	67	427	24	4,925	268
1978	5,608	24	12	97	466	20	5,061	273
1979	5,777	20	10	78	498	19	5,213	278
1980	5,806	19	5	143	499	19	5,169	272
1981	5,825	19	5	234	507	18	5,090	266
1982	5,802	18	3	158	506	20	5,138	266
1983	5,659	20	23	86	500	9	5,108	262
1984	5,709	9	32	58	530	11	5,151	262
1985	5,710	11	13	71	548	11	5,104	257
1986	5,766	11	14	102	567	10	5,112	255
1987	5,868	10	6	111	599	14	5,160	255
1988	5,784	14	5	142	606	15	5,041	247
1989	5,598	15	25	92	643	11	4,892	237
1990	5,665	11	9	101	678	12	4,894	235
1991	5,758	12	2	154	708	13	4,896	233

Source: *Agricultural Statistics*, USDA, various years.

Table 4. Prices Received by Egg Producers for All Eggs and Net Returns (1972-1992) and Prices Received for Table Eggs (1982-1992)

Year	All Eggs	Net Returns	Year	All Eggs	Table Eggs[1]	Net returns
	¢/doz.	¢/doz.		¢/doz.	¢/doz.	¢/doz.
1972	30.9	-2.8	1982	59.5	53.0	3.8
1973	52.5	6.2	1983	61.1	57.8	3.3
1974	53.2	-0.4	1984	72.3	64.0	8.9
1975	52.4	1.0	1985	57.2	50.0	1.5
1976	58.3	10.0	1986	61.5	53.8	6.9
1977	55.6	3.8	1987	54.7	44.1	0.2
1978	52.2	1.7	1988	52.8	44.3	-5.0
1979	58.3	3.1	1989	68.9	62.5	15.2
1980	56.3	-3.5	1990	70.9	63.7	16.6
1981	63.1	0.4	1991	67.6	56.7	12.5
			1992	56.0	45.1	1.9

[1]Does not include hatching eggs. These prices were not available before 1981.
Source: *Livestock and Poultry Situation and Outlook,* ERS/USDA, various issues.

Review of Egg Composition and Related Flaxseed Feeding Research

In recent years, egg consumption has been adversely affected by the consumers' concerns regarding concentration of cholesterol in egg yolks. More precise cholesterol assays have been developed that measure the average cholesterol level at 213 mg per egg yolk, compared with published values of 275 mg of cholesterol in a large egg (Sim et al. 1991; Jiang et al. 1991). Research has been conducted to find a method to reduce cholesterol levels in eggs and to enhance the acceptability of eggs in human diets (Yu and Sim 1989; Olomu and Baracos 1990; Jiang et al. 1990; Cherian and Sim 1991a; Sim et al. 1991).

Intake of omega-3 fatty acids may reduce blood and liver cholesterol levels, reduce the risk of coronary and heart disease, and suppress inflammation (Jiang and Sim 1991; Olomu and Baracos 1991). Omega-3 fatty acids are primarily available in seeds and plants from cold climates and green leafy vegetables and in oils extracted from cold-water fish like mackerel, salmon, tuna, and cod (Johnston and Johnston 1990). Animals and humans can convert the fatty acid derived from flax to similar types of fatty acids found in fish oil (Cherian and Sim 1991b).

The egg yolk lipid composition is influenced by dietary fat, and the total omega-3 fatty acid content could be enriched through the diet of laying hens (Belnave 1970; Cherian and Sim 1991a). Eggs enriched with omega-3 fatty acids can provide dietary omega-3 fatty acids, and at the same time, may lower blood cholesterol levels (Jiang and Sim 1991). Storage of omega-3 enriched eggs was not affected under current egg handling conditions, and feeding 8 and 16 percent flaxseed in rations to laying hens did not adversely affect egg production (Sim 1990). However, in a sensory evaluation in studies completed in Canada, 36 percent of the participants reported a fish or fish-related flavor for eggs from hens fed higher levels (15 to 16 percent) of ground flaxseed (Jiang et al. 1992). In research to determine

what components of the flaxseed diet are responsible for the off flavors, rancidity in the feed was reported to cause the fishy flavor. Feeding whole flaxseed or adding vitamin E (an antioxidant) to the ration can prevent rancidity, and no fishy taste has been detected in eggs from rations that were as high as 20 percent whole flaxseed (Scheideler 1993; Gretebeck 1993). Proper flock management in ration preparation can reduce or eliminate whole flaxseed from passing through the birds (Gretebeck 1993). In related research, feeding flaxseed to meat birds enriched the chicken meats with omega-3 fatty acids, with a concomitant reduction of saturated fatty acids (Ajuyah et al. 1991). These findings could enhance the image of eggs to the health-conscious public and increase per capita consumption. If an increase in per capita consumption of eggs from hens fed flax occurs, then the demand for flaxseed would subsequently increase.

Flaxseed in Poultry Rations

An objective of this study was to estimate the impact of increasing use of flaxseed into feed rations for laying hens. Full-fat oil seeds ordinarily are not used as a feedstuff for poultry, but when fully utilized, should be an excellent dietary energy/protein/omega-3 fatty acid source. Several studies have included flaxseed and other feed ingredients containing omega-3 fatty acids into poultry rations. Cherian and Sim (1991a) fed two levels (8 and 16 percent) of flaxseed in wheat/barley/soybean rations. Flaxseed and menhaden oil were used in corn/soybean rations in a poultry feeding trial in Texas (Van Elswyck 1993). The variable ingredients in each of these rations and a cost for those ingredients as a portion of the entire ration are listed in Tables 5 and 6.

Good News Eggs,™ developed by the Hamilton Farm Bureau Cooperative, Hamilton, Michigan, is feeding a 15 percent flaxseed ration to laying hens. They have 14 franchises in Michigan, Indiana, Connecticut, Illinois, Tennessee, Texas, Florida, and California, producing eggs with higher omega-3 fatty acid content than eggs from laying hens not fed flaxseed. Good News Eggs™ plan for a $.40/dozen premium for eggs higher in omega-3 fatty acids in this niche market. They have approximately 3 percent of the U.S. egg market with minimum advertizing. They see a potential for capturing 10 percent of the U.S. egg market (Stroburg 1993). This could increase profitability of egg production, depending on the price of flaxseed ingredients in the ration (Table 4).

The cost for the variable ingredients in each ration was calculated, assuming five pounds of feed per dozen eggs produced and using the percentage of variable ingredients in the ration. The prices for ingredients are listed in the footnotes of Tables 5 and 6. The cost of variable ingredients (84.6 percent of the complete ration) in the control ration in the wheat/barley/soy study was $.27 per dozen eggs. The cost of variable ingredients for the 8 percent flaxseed ration was $.28 per dozen eggs, while the 16 percent flaxseed ration was slightly less at $.26 per dozen eggs. An average shipping cost from the Upper Midwest, where most U.S. flax is produced, is included in the price for flaxseed shipped to areas where eggs are produced.

The cost for variable ingredients in the corn/soy rations, which would be more traditional in egg-producing areas, was also estimated in the same manner as the wheat/barley/soy ration. The cost for the control ration (90.0 percent of the complete ration) was $.24 per dozen eggs. The ration, using 15 percent whole flaxseed, cost $.30 per dozen eggs, while the 15 percent ground flaxseed ration cost $.28 per dozen eggs for the variable ingredients. This trial included a ration using 1.5 percent menhaden oil, another omega-3 fatty acid source. This ration cost $.25 per dozen eggs, but fish oil may be more difficult to obtain than flaxseed.

Table 5. Wheat/Barley/Soybean/Flaxseed Feeding Trial Rations for Laying Hens, Variable Ingredients, and Cost, 1993.

Variable Ingredients	Control	Pounds/ Ton	Cost	Flax 8%	Pounds/ Ton	Cost	Flax 16%	Pounds/ Ton	Cost
	(%)			(%)			(%)		
Barley	7.0	140	5.45	17.5	350	13.64	21.6	432	16.83
Wheat	41.0	820	44.42	26.0	520	28.17	30.0	600	32.50
Soybean meal	19.6	392	39.59	18.0	360	36.36	15.0	240	24.24
Starch	17.0	340	37.47	15.1	302	33.28	5.0	100	11.02
Flaxseed	0.0	0	0.00	8.0	160	18.57	16.0	320	38.74
Total for variable ingredients/ton			$126.93			$130.01			$123.33
Percent of ration			84.6%			84.6%			84.6%
Cost per dozen eggs for variable ingredients[1]			$0.2685			$0.2767			$0.2608
Additional return over variable feed costs with premium for omega-3 eggs									
Premium:		$.10/doz				$0.0918			$0.1076
		$.20/doz				$0.1918			$0.2076
		$.30/doz				$0.2918			$0.3076
		$.40/doz				$0.3918			$0.4076

[1]Cost per dozen eggs assumes 5 pounds of feed/dozen eggs multiplied by the percentage of variable ingredients in each ration.

Prices for variable ingredients:		
	Barley	$1.87/bu
	Wheat	$3.25/bu
	Soybean Meal	$202.00/ton
	Starch	$0.11/lb
	Flaxseed	$5.00/bu plus 1.50/bushel transportation

Table 6. Corn/Soybean/Flaxseed/Menhaden Oil Feeding Trial Rations for Laying Hens, Variable Ingredients, and Cost, 1993.

Variable Ingredients	Control Ration	Lbs./ Ton	Cost	Fish oil 1.5%	Lbs./ Ton	Cost	Whole Flax 15%	Lbs./ Ton	Cost	Grnd Flax 15%	Lbs./ Ton	Cost
	(%)			(%)			(%)			(%)		
Yellow corn	72.49	1450	69.35	70.48	1410	67.43	56.53	1131	54.08	62.94	1260	60.21
Soybean meal	16.74	335	33.81	17.11	342	34.56	13.02	260	26.30	7.80	156	15.76
Animal/veg. fat	0.78	16	2.26	0	0	0.00	5.69	114	16.50	4.61	92	13.32
Menhaden oil	0.0	0	0.00	1.53	30	8.40	0	0	0.00	0	0	0.00
Whole flax	0.0	0	0.00	0	0	0.00	15.00	300	34.82	0	0	0.00
Ground flax	0.0	0	0.00	0	0	0.00	0	0	0.00	15.00	300	52.23
Total variable ingredients/ton			$105.43			$110.39			$131.70			125.66
Percent of ration			90.0%			89.1%			90.2%			90.4%
Cost per dozen eggs for variable ingredients[1]			$0.2372			$0.2459			$0.2971			$0.2838
Additional return over variable feed costs with premium for omega-3 eggs												
Premium: $.10/doz						$0.0914			$0.0401			$0.0534
$.20/doz						$0.1914			$0.1401			$0.1534
$.30/doz						$0.2914			$0.2401			$0.2534
$.40/doz						$0.3914			$0.3401			$0.3534

[1]Cost per dozen eggs assumes 5 pounds of feed/dozen eggs times the percentage of variable ingredients in each ration.

Prices for variable ingredients:		
Corn	$2.87/bu	
Soybean Meal	$202.00/tn	
Animal/vegetable Fat	$0.145/lb	
Menhaden Oil	$0.28/lb	
Flaxseed	$5.00/bu	plus 1.50/bu transportation
Ground Flaxseed	$5.00/bu	plus $1.50/bu transportation and $ .28/bu grinding.

If producers were to receive a $.40 premium for eggs with increased omega-3 fatty acids, all of the rations that increase the omega-3 fatty acids would be competitive as poultry rations. The net returns over variable ingredients in the wheat/barley/soybean rations when receiving a $.40 premium are estimated to be $.39 and $.41 per dozen for 8 and 16 percent flaxseed rations, respectively (Table 5). In the corn/soybean hen rations, the estimated net return is $.34 and $.35 per dozen eggs, respectively, for 15 percent whole and ground flaxseed included in the ration (Table 6).

Egg producers, who adopt flaxseed into their layer rations, should be aware that the possibility for a $.40 premium is not guaranteed. Producers may not be able to sell all of their production for a premium. And, as more producers include flaxseed in their rations, the premium may decrease. Returns to producers of $.10 to .40 per dozen eggs over variable feed costs for premium prices per dozen eggs are included in Tables 5 and 6. Some consumers perceptions of eggs may not change, even though omega-3 eggs are considered more healthful.

Impact of Flaxseed Use in Poultry Rations

Adding flaxseed to poultry rations would increase the demand for flaxseed. Flaxseed production needed to meet the demand for different levels of feeding was estimated. If 20 percent of egg production was from layers fed rations containing 8, 15, or 16 percent flaxseed, 556,039 to 1.12 millon acres of flax would be needed to meet the increased demand for flaxseed at 15.1 bushels of flaxseed per acre. In alternate scenarios, if 10 percent of egg production were from hens fed flaxseed in their rations, 278,020 to 556,039 acres (at 8 to 16 percent flaxseed), or for 6 percent adoption, 166,812 to 333,632 acres of flax would be needed to meet the demand for flaxseed. North Dakota flax producers, who raised 83 percent of the U.S. flax produced in 1992, harvested 140,000 acres. For a 16 percent flaxseed ration and 6 percent adoption rate, this would be two and one-half times the 1992 North Dakota harvested acres. The estimated acreage for flaxseed is shown in Table 7.

Table 7. Acreage of Flax Needed for 8, 15, and 16 Percent Flaxseed in Laying Hen Rations, 1993.

Dozen eggs produced (1992)	5,877.33	million
Feed required (5 lb/dozen eggs)	29,386.67	million pounds

Flaxseed needed in rations:

	Adoption rate by producers		
Ration	6%	10%	20%
(%)	(acres[1])	(acres[1])	(acres[1])
8.0	166,812	278,020	556,039
15.0	312,772	521,287	1,042,573
16.0	333,623	556,039	1,112,078

[1]Assuming 15.1 bushels per acre.

Flaxseed Production in North Dakota

Flax is an excellent crop for rotational use. It does not require additional equipment expense and uses fewer inputs than wheat or barley. Since flax is not government program price supported, it can be planted on flex acres. Flaxseed yields are generally lower than hard red spring wheat (HRSW), so to be competitive in a farming enterprise, the price must increase from current levels.

North Dakota produced 83% of the U.S. flaxseed in 1992. The majority of the North Dakota production is in the north central and northeastern regions. To estimate a competitive price for flaxseed with HRSW, a five year average for price and yield of flaxseed in the north central and northeast regions of North Dakota was used (ND Agricultural Statistics Service 1993). Production costs for these regions were established using North Dakota State University Extension Service Crop Budget Generator (Haugen et al. 1992). Gross income for both enterprises were determined, as well as the price necessary for flaxseed to equal net income for nonprogram wheat (Table 8). Using the assumptions presented in Table 8, a 12.3% increase in flax price from $5.45 to $6.12 is necessary to provide the same net cash flow as nonprogram wheat.

Table 8. Price Sensitivity for Hard Red Spring Wheat and Flax, North Central and Northeast North Dakota, 1988 Through 1992 Average

		Flaxseed	
5-Year average	HRSW	Present	Projected
Yield (bu/acre)	29.35	13.98	13.98
Price/bushel	$3.17	$5.45	$6.12
Gross income	$93.16	$76.12	$85.56
Cash flow			
Direct costs	47.63	40.97	40.97
Fixed costs	30.64	29.71	29.71
	78.27	70.68	70.68
Net cash flow	$14.89	$5.44	$14.88

Source: North Dakota Agricultural Statistics Service, various issues. Haugen et al. 1992, NDSU Extension Service Crop Budget Generator.

Impacts of Increased Flaxseed Price

If the price of flaxseed were increased to $6.12/bu., to become competitive with nonprogram wheat in north central and northeast regions of North Dakota, the net returns per dozen eggs would be reduced. The cost of variable ingredients in laying hen rations in both feeding trials, and additional return over variable feed costs with different premiums is shown in Tables 9 and 10. The returns were reduced due to increased price for flaxseed, but would still be competitive when a premium is received for eggs from laying hens with flaxseed included in their rations

Table 9. Cost for Variable Ingredients in Wheat/Barley/Soybean/Flaxseed Feeding Trial and Additional Returns Over Cost of Variable Ingredients for $.10, .20, .30, .40 Premiums, 1993

	Control	Flax 8%	Flax 16%
Cost/ton for variable ingredients	$126.93	$134.01	$129.73
Cost per dozen eggs for variable ingredients	$0.2685	$0.2834	$0.2744
Additional return/dozen eggs over variable costs with premium for omega-3 eggs			
Premium: $.10/doz	0	$0.0850	$0.0941
$.20/doz	0	$0.1850	$0.1941
$.30/doz	0	$0.2850	$0.2941
$.40/doz	0	$0.3850	$0.3941

Table 10. Cost for Variable Ingredients in Corn/Soybean/Flaxseed/Menhaden Oil Feeding Trial and Additional Returns Over Cost of Variable Ingredients for $.10, .20, .30, .40 Premiums, 1993

	Control	Fish Oil	Whole Flax 15%	Grnd Flax 15%
Cost/ton for variable ingredients	$105.43	$110.39	$137.70	$131.66
Cost per dozen eggs for variable ingredients	$0.2372	$0.2459	$0.3107	$0.2974
Additional return/dozen eggs over variable costs with premium for omega-3 eggs				
Premium: $.10/doz	0	$0.0914	$0.0266	$0.0398
$.20/doz	0	$0.1914	$0.1266	$0.1398
$.30/doz	0	$0.2914	$0.2266	$0.2398
$.40/doz	0	$0.3914	$0.3266	$0.3398

Summary

The poultry industry has changed from a home industry to a specialized production industry. The concentration of laying hens has moved from the Corn Belt area to South Atlantic and South Central regions since World War II. Per capita egg consumption has declined from 312 in 1963 to 235 in 1992. At the same time, production per hen has increased from 125 eggs/year in 1925 to 254 in 1992. The number of laying hens has not changed from 1972 to 1992, indicating that an increase in population has absorbed the increase in production.

Flaxseed contains omega-3 fatty acids, which appear to benefit the human cardiovascular system by reducing low-density lipids, cholesterol, and blood platelet stickiness. Poultry rations containing flaxseed can increase levels of omega-3 fatty acids in egg yolks, and improvement of the omega-6/omega-3 fatty acid ratio. However, in sensory evaluations, panelists detected a fishy or fish-related flavor, but further research has provided management practices to control this perceived problem; and, in later sensory evaluations, no fishy flavor was detected. Data from research in Canada indicate a benefit to people consuming "flax eggs," that is, the people consuming several eggs/week had no increase or some decrease of LDL cholesterol and triglycerides in their blood. These findings could improve the image of eggs to the health-conscious public.

Adoption of flaxseed into poultry rations for laying hens would increase demand of flaxseed. To meet this demand, at 20 percent adoption, 556,039 to 1,112,078 acres of flax would be needed for 8 to 16 percent flaxseed in poultry rations at 15.1 bu/acre. If 10 percent of the producers adopted the flaxseed rations, 278,139 to 556,039 acres (8 and 16 percent adoption) would be needed to meet the demand.

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Appendix

Appendix Table 1. Number of Laying Hens and Pullets by Region, United States, 1970-1991

Year	North Atlantic	North Central	W. North Central	South Atlantic	South Central	Western	Alaska & Hawaii
	----------	----------	----------	1,000 head	----------	----------	----------
1965	46,792	44,115	53,634	54,449	61,018	46,998	904
1970	43,957	44,047	42,936	67,702	68,045	56,194	964
1975	35,821	41,168	33,754	59,842	56,923	51,256	979
1980	39,774	42,420	31,945	63,948	63,502	51,599	1,035
1985	38,397	50,220	29,470	56,348	56,505	47,786	1,043
1990	32,981	50,267	32,658	55,091	53,219	45,151	979

Source: *Livestock and Poultry Situation and Outlook*, USDA, various issues.

Appendix Table 2. U.S. Egg Production by Region, 1965-1992

Year	North Atlantic	North Central	W. North Central	South Atlantic	South Central	Western	Alaska & Hawaii
	----------	----------	----------	million eggs	----------	----------	----------
1965	9,565	9,281	11,274	10,588	12,550	12,285	197
1970	9,820	9,489	9,934	14,777	14,010	12,545	202
1975	9,365	8,588	7,670	13,716	12,182	12,449	214
1980	9,795	9,702	7,287	15,075	14,617	13,330	226
1985	9,893	12,391	7,043	13,751	15,117	12,706	232
1990	8,853	13,221	8,322	13,487	14,233	12,574	229
1992	9,450	13,258	10,145	13,347	14,618	12,869	223

Source: *Livestock and Poultry Situation and Outlook*, USDA, various issues.