

**A Mushroom Forecasting Model:  
Review and Evaluation**

**Prepared for the  
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## **A Mushroom Forecasting Model: Review and Evaluation**

### **Overview**

The model described here is used to develop forecasts on annual U.S. mushroom area (total fillings), yield, production, allocation (fresh vs. processed), utilization, grower price, imports, and exports. For most of these variables, forecasts are obtained for both fresh and processed mushrooms. However, the analysis is limited to *Agaricus* mushrooms, which includes both white and brown mushrooms. Specialty mushrooms are not included in the analysis due to a lack of time series data, which is required for estimation of the model parameters.

The model is composed of a system of equations, incorporating the economic relationships that are observed in the marketplace and specified by economic theory. Parameters for the model are estimated econometrically. In total, there are 27 different econometric equations and 7 identities, which use predicted values from the econometric equations. The data for most variables included in the model extend from 1981/82 to 2001/02 for a July 1 to June 30 marketing year. This is the time period used to estimate most of the model's parameters. All of the econometric equations are linear in form, though some are double logarithmic equations. Usually, linear equations are preferred for simulation models used to develop forecasts, as they are more robust in their performance.

Overall, the system may be described as a recursive system of equations, which, through a stepwise fashion, produces one-step ahead forecasts, while maintaining a market equilibrium. The equilibrium requires total supply to equal total utilization in each year. This equilibrium is achieved in both the fresh and processed market by allowing the retail and processed prices to adjust. The retail prices are then transmitted back through the system to determine grower prices, area, production, allocation, utilization, imports, and exports. Once an equilibrium is achieved in one year, the model solves for an equilibrium in the next year. This step-wise process continues through to the last forecast year. Many of the equations utilize lagged variables. Therefore, an equilibrium must be achieved in one year, before the equilibrating process proceeds in the next. Several of the model's equations also use macroeconomic variables. Forecasts on these variables are obtained from economic forecasting and advisory service, Global Insight, formerly DRI-WEFA. Currently, forecasts are prepared for marketing years 2002/03 through 2012/13.

### **Model Structure**

The model incorporates three production regions in the United States—California, Pennsylvania, and Other United States. Total values (area and production) for the United States are developed by summing over these regions. Although the model consists of 27 estimated equations and 7 identities, many of these equations are estimated for each regions. Therefore, we can describe the model in terms of sets of equations, beginning with the area equations.

1. Area (California, Pennsylvania, Other U.S.)  
The area equations provide a structure for predicting the total area under production in each region, based on the observed relationships in the past. Although the specification varies slightly by region, area is typically specified as a function of last year's area and last year's average grower price.
2. Yield Equations (California, Pennsylvania, Other U.S.)  
The yield equations provide forecasts on yield. These equations typically model yield as a function of time, which reflects improvements in technology and production practices.
3. Production (California, Pennsylvania, Other U.S.)  
Total production is specified as an identity using the predicted values from the area and yield equations. (Production = Area x Yield)
4. Fresh Allocation (California, Pennsylvania, Other U.S.)  
The amount of total production allocated to the fresh market is determined by the allocation equations. Again, the estimated equations vary by region. However, the amount allocated to the fresh market is typically specified as a function of past fresh volumes and fresh and processed grower prices.
5. Processed Allocation (California, Pennsylvania, Other U.S.)  
The amount of production allocated to the processed market is determined through an identity, which is expressed as total production minus fresh allocation.
6. Fresh Imports (U.S.)  
Total U.S. fresh mushroom imports are explained by import price and total U.S. disposable income, as economic theory would specify for an import demand function. In this model, the U.S. import price for Canadian mushrooms serves a proxy measure for import price, since it is currently the largest supplier to the United States.
7. Fresh Exports (U.S.)  
U.S. fresh mushroom exports are modeled as a function of the U.S. fresh grower price and the Canadian gross domestic product. Furthermore, the grower price is converted into Canadian dollars. This specification recognizes that Canada is also the largest export destination for U.S. fresh mushrooms.
8. Processed Imports (U.S.)  
Processed imports are specified as a function of the U.S.-Canadian exchange rate and U.S. disposable income.
9. Processed Exports (U.S.)  
Processed exports are explained by changes in the U.S.-Canadian exchange rate, Canadian gross domestic product, and lagged exports.

10. U.S. Fresh Demand (U.S.)

U.S. consumer demand for fresh mushrooms is explained by the retail price for mushrooms and disposable income.

11. Fresh Margin (U.S.)

The model is based on the assumption that retail prices adjust to bring equilibrium between supply and demand. However, the signal offered by retail prices must be transmitted back to the farm level. Then, acreage and allocation decisions are made based on grower prices. The fresh margin equation provides a link between the retail fresh price and the grower fresh price.

12. Processed Demand (U.S.)

Consumer demand for processed mushrooms is specified as a function the retail processed price and consumer expenditures on food and beverages.

13. Processed Margin (U.S.)

The processing margin equation provides a link between retail and grower prices.

14. Price Linkage Equations

In addition to providing an explanation on how changes in retail prices are transmitted to the grower level, it is also necessary to explain the relation between fresh and processed prices in each region.

a. Average Grower Price (U.S., California, Pennsylvania, Other U.S.)

Weights are applied to fresh and processed prices to provide forecasts on an average grower price.

b. Fresh Grower Price (California, Pennsylvania, Other U.S.)

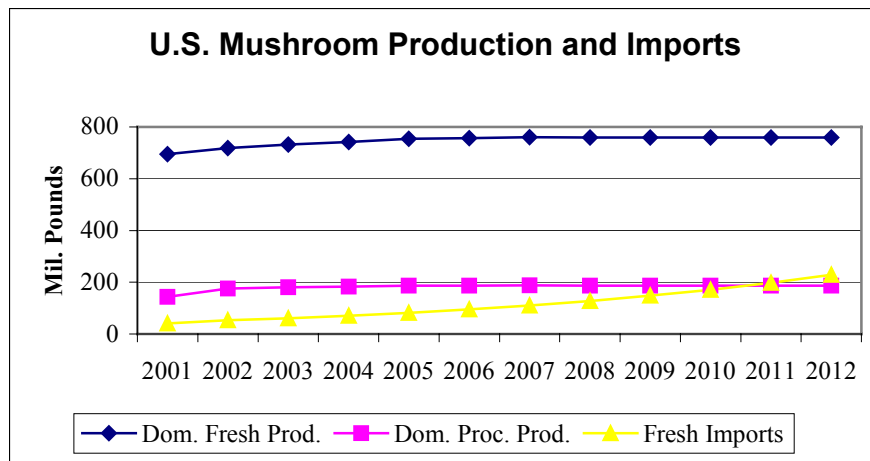
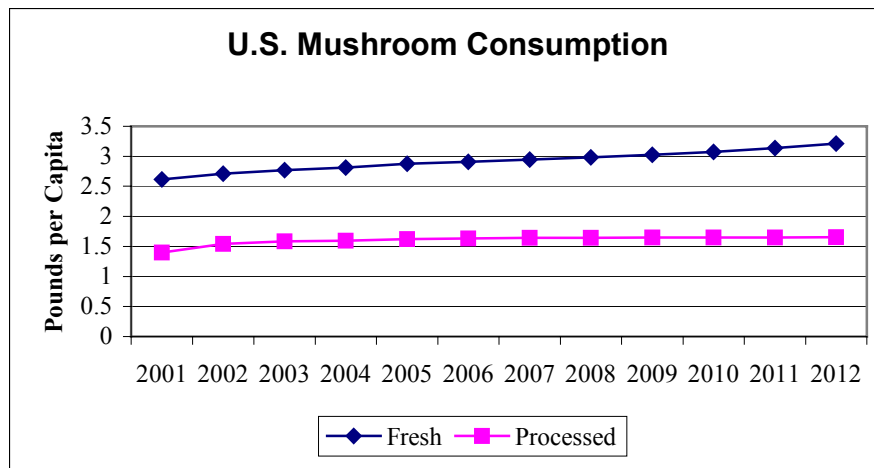
It is also necessary to explain how grower prices are determined in each region for fresh and processed mushrooms.

c. Processed Grower Price (California, Pennsylvania, Other U.S.)

Each of the models and their corresponding variables are further described in appendix table 1. In addition to describing the models and their corresponding variables, the data source for each variable is also listed. The model forecasts are prepared using these equations to simulate market conditions into the future. As described earlier, an equilibrium is achieved in each year for both the fresh and processed markets, where total supply (production plus imports) equals total utilization (exports plus consumption). Highlights of the market outlook presented in appendix table 2 are discussed in the next section.

## Outlook Highlights

U.S. fresh mushroom consumption may increase at 1.9% per year, reaching 3.21 pounds per person by 2012. Meanwhile, processed mushroom consumption is expected to remain flat at about 1.65 pounds per person through 2012. The modest growth in fresh mushroom consumption is projected to be increasingly served by imports. After some near term growth, U.S. fresh mushroom production will remain relatively stable over the forecast period, increasing by less than one percent per year. However, fresh mushroom imports are projected to increase by about 17% per year, growing from about 40 million pounds to 228 million pounds in 2012. The lackluster growth in domestic production reflects a projected slow growth in fresh grower price, which will increase by only 0.5% per year. U.S. export shipments are also expected to remain relatively flat at about 1.49 million per year.



## **Macroeconomic Assumptions**

These forecasts are made based on some underlying assumptions on the performance of the U.S. and international economy. The macroeconomic data needed for developing the model are obtained from Global Insights, formerly DRI\_WEFA. In regards to the mushroom model, the principal macroeconomic variables are the U.S. gross domestic product, which drive food and beverage expenditures, and the value of the dollar. Following nearly zero growth in 2001, real U.S. GDP growth improves every year through the 2004, before settling into a long-range rate of about 3% per year. Meanwhile, the U.S. dollar will decline in strength against most industrial economy currencies throughout the forecast period. Indeed, the dollar is expected to even weaken relative to the Canadian dollar beginning in 2004. This will of course make imports of mushrooms from relatively more expensive. However, the dollar will appreciate relative to most developing economies.

## **Evaluation**

The model's framework is consistent with economic theory and observations on industry structure and performance. This consistency is also achieved through a parsimonious specification, which aids in making robust forecasts. The model will benefit from new reports on area, production, and price available from the USDA's National Agricultural Statistical Service in August 2003. At this time, the model's data can be updated and the model parameters can be re-estimated using this additional year's data. This too would be a time to re-evaluate the structure of some of the model's estimated equations. Areas for potential improvement include possibly the domestic consumption equation and the import and export equations.

**Appendix Table 1. Mushroom Model Variables.**

<b>Dependent Variables</b>	<b>Units of Measure</b>	<b>Date Source</b>
<b>Independent Variables</b>		
California Acreage	1,000 sq ft	NASS, Mushrooms, August 2002
Lagged California Acreage	1,000 sq ft	NASS, Mushrooms, August 2002
Lagged California Average Grower Price	cents/lb	NASS, Mushrooms, August 2002
California Yield	lbs./sq. ft.	Computed from production and yield
Time trend		
California Production	1,000 lbs	NASS, Mushrooms, August 2002
California Acreage * California Yield		
Pennsylvania Acreage	1,000 sq. ft.	NASS, Mushrooms, August 2002
Lagged Pennsylvania Acreage	1,000 sq. ft.	
Two year moving average (t, t-1)		
Pennsylvania average grower price	cents/lb	NASS, Mushrooms, August 2002
Pennsylvania Yield	lbs/sq. ft.	Computed from production and yield
Time Trend		
Pennsylvania Production	1,000 lbs	NASS, Mushrooms, August 2002
Penn. Acreage * Penn. Yield		
Other U.S. Acreage	1,000 sq ft	NASS, Mushrooms, August 2002
Four year moving average price (t, t-3)		
Other U.S. Average Grower Price	cents/lb.	NASS, Mushrooms, August 2002
Other U.S. Yield	lbs/sq ft	Computed from production and yield
Time Trend		
Other U.S. Production	1,000 lbs	NASS, Mushrooms, August 2002
Other U.S. Acreage * Other U.S. Yield		
U.S. Acreage	1,000 sq ft	NASS, Mushrooms, August 2002
Penn. Acreage + Oth. U.S. Acreage + Ca. Acreage		

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**Appendix Table 1. Continued.**

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<b>Dependent Variables</b>	<b>Units of Measure</b>	<b>Data Source</b>
<b>Independent Variables</b>		
U.S. Production	1,000 lbs	NASS, Mushrooms, August 2002
Penn. Acreage * Penn. Yield + Oth. U.S. Acreage * Oth. U.S. Yield + Calif. Acreage * Calif. Yield		
California Fresh Allocation	1,000 lbs	NASS, Mushrooms, August 2002
California Fresh Grower Price	Cents/lb	NASS, Mushrooms, August 2002
California Production	1,000 lbs	NASS, Mushrooms, August 2002
California Processed Allocation	1,000 lbs	NASS, Mushrooms, August 2002
Calif. Prod. - Calif. Fresh Allocation		
Pennsylvania Fresh Allocation	1,000 lbs	NASS, Mushrooms, August 2002
Lagged Penn. Fresh Allocation	1,000 lbs	NASS, Mushrooms, August 2002
Ratio Penn. Fresh Grower Price to Penn. Proc. Grower Price	Index	NASS, Mushrooms, August 2002
Pennsylvania Proc. Allocation	1,000 lbs	NASS, Mushrooms, August 2002
Penn. Prod. - Penn. Fresh Allocation		
Other U.S. Fresh Allocation	1,000 lbs.	NASS, Mushrooms, August 2002
Other U.S. Fresh Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Other U.S. Production	1,000 lbs	NASS, Mushrooms, August 2002
Other U.S. Proc. Allocation	1,000 lbs	NASS, Mushroom, August 2002
Other U.S. Prod. - Other U.S. Fresh Allocation		
U.S. Fresh Imports	1,000 lbs	Census; ERS, U.S. Mushroom Statistics, March 2003
Log(U.S. Imp. Price Canadian Fresh)	log(cents/lb)	Census; Forecast external
Log(U.S. per capita disposable income)	log(\$1,000)	Global Insight

**Appendix Table 1. Continued.**

<b>Dependent Variables</b>	<b>Independent Variables</b>	<b>Units of Measure</b>	<b>Data Source</b>
U.S. Fresh Exports	U.S. Fresh Grower Price * U.S.-Can. Ex. Rate	1,000 lbs cents/lb;	Census; ERS, U.S. Mushroom Statistics, May 2003
	Canadian Gross Domestic Product	Can\$/US\$ Index	NASS, Mushrooms, August 2002; Global Insight (DRI-WEFA)
			Global Insight
U.S. Processed Imports	U.S.- Canadian Exchange Rate	1,000 lbs. (Fresh equivalent)	ERS, U.S. Mushroom Statistics, May 2003
	U.S. disposable income	\$Can/\$US	Global Insight
		\$1,000	Global Insight
Log(U.S. Processed Exports)	Log(Lag U.S. Procesed Exports)	1,000 lbs. (Fresh equivalent)	ERS, U.S. Mushroom Statistics, May 2003
	Log(U.S. Canadian Exchange Rate)	log(1,000 lbs)	
	Log(Real Canadian GDP)	log(\$Can/\$US)	Global Insight
		log(Index)	Global Insight
U.S. Fresh Demand	U.S. Fresh Retail Price	lbs/capita (Farm)	ERS, U.S. Mushroom Statistics, May 2003
	U.S. per capita disposable income	cents/lb.	Supermarket Business, Sept 2002
		\$1,000	Global Insight
Fresh Margin	U.S. Fresh Retail Price	cents/lb.	U.S. Retail Price Fresh - U.S. Grower Price, Fresh
		cents/lb.	Supermarket Business, Sept 2002
Processed Demand	U.S. Processed Retail Price x 100 / Retail Price Deflator	lbs/capita (fresh equiv)	ERS, U.S. Mushroom Statistics, May 2003
	Per capita expenditures food & beverages x 100 / retail price index	cents/lbs; Index	
		\$1,000; Index	Global Insight
Processing Margin	Log(U.S. Processed Retail Price)	cents/lb	
	Log(Time trend)	log(cents/lb)	

**Appendix Table 1. Continued**

<b>Dependent Variables</b>	<b>Units of Measure</b>	<b>Data Source</b>
<b>Independent Variables</b>		
U.S. Average Grower Price	cents/lb.	NASS, Mushrooms, August 2002
U.S. Fresh Grower Price	cents/lbs	NASS, Mushrooms, August 2002
U.S. Processed Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Time trend		
California Fresh Grower Price	cents/lb	NASS, Mushrooms, August 2002
U.S. Fresh Grower Price	cents/lb	NASS, Mushrooms, August 2002
California Processed Grower Price	cents/lb	NASS, Mushrooms, August 2002
U.S. Processed Grower Price	cents/lbs	NASS, Mushrooms, August 2002
California Average Grower Price	cents/lbs	NASS, Mushrooms, August 2002
California Fresh Grower Price	cents/lbs	NASS, Mushrooms, August 2002
California Processed Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Pennsylvania Fresh Grower Price	cents/lbs	NASS, Mushrooms, August 2002
U.S. Fresh Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Pennsylvania Processed Grower Price	cents/lbs	NASS, Mushrooms, August 2002
U.S. Processed Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Pennsylvania Average Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Pennsylvania Fresh Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Pennsylvania Processed Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Other U.S. Fresh Grower Price	cents/lbs	NASS, Mushrooms, August 2002
U.S. Fresh Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Other U.S. Processed Grower Price	cents/lbs	NASS, Mushrooms, August 2002
U.S. Processed Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Other U.S. Average Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Other U.S. Fresh Grower Price	cents/lbs	NASS, Mushrooms, August 2002
Other U.S. Processed Grower Price	cents/lbs	NASS, Mushrooms, August 2002

**Appendix Table 2: U.S. Mushroom Supply and Utilization**

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>DOMESTIC PRODUCTION:</b>												
CA Acreage ( 1000 Sq. Ft)	22,776	22,889	22,958	22,976	22,966	22,961	22,959	22,959	22,960	22,960	22,960	22,960
CA Yield (Lbs. Per Sq. Ft.)	5.63	5.75	5.71	5.65	5.68	5.67	5.67	5.67	5.67	5.67	5.67	5.67
CA Production (1000 Lbs.)	128,320	131,667	131,004	129,844	130,489	130,076	130,279	130,166	130,233	130,199	130,219	130,208
CA Fresh Alloc. (1000 Lbs.)	118,838	116,728	116,261	115,304	115,914	115,676	115,922	115,878	115,977	115,991	116,105	116,186
CA Proc. Alloc (1000 Lbs.)	9,482	14,938	14,744	14,541	14,575	14,399	14,357	14,288	14,256	14,209	14,114	14,022
PA Acreage (1000 Sq. Ft)	79,286	80,850	83,721	84,730	86,205	86,172	86,251	85,750	85,483	85,085	84,880	84,646
PA Yield (Lbs. Per Sq. Ft.)	5.80	6.04	6.09	6.12	6.13	6.16	6.18	6.19	6.21	6.22	6.23	6.24
PA Production (1000 Lbs.)	459,593	488,538	510,175	518,179	528,789	530,841	532,680	531,010	530,677	529,248	528,978	528,394
PA Fresh Alloc. (1000 Lbs.)	353,219	362,984	379,060	385,007	392,890	394,415	395,781	394,540	394,293	393,231	393,031	392,597
PA Proc. Alloc (1000 Lbs.)	106,374	125,554	131,115	133,172	135,899	136,426	136,899	136,470	136,384	136,017	135,947	135,797
Other U.S. Acreage (1000 Sq. Ft)	44,950	48,630	48,173	48,817	49,502	49,838	50,014	50,106	50,154	50,179	50,192	50,199
Other U.S. Yield (Lbs. Per Sq. Ft.)	5.56	5.62	5.63	5.66	5.67	5.68	5.69	5.69	5.70	5.70	5.70	5.70
Other U.S. Production (1000 Lbs.)	249,953	273,072	271,264	276,069	280,602	283,113	284,505	285,320	285,776	286,028	286,150	286,192
Other U.S. Fresh Alloc. (1000 Lbs.)	222,480	238,392	236,814	241,008	244,966	247,158	248,373	249,084	249,482	249,703	249,809	249,845
Other U.S. Proc. Alloc (1000 Lbs.)	27,473	34,680	34,451	35,061	35,636	35,955	36,132	36,236	36,294	36,326	36,341	36,346
U.S. Acreage (1000 Sq. Ft)	147,012	152,370	154,851	156,523	158,672	158,971	159,224	158,815	158,597	158,224	158,031	157,804
U.S. Yield (Lbs. Per Sq. Ft.)	5.73	5.86	5.89	5.90	5.92	5.94	5.95	5.96	5.97	5.98	5.98	5.99
U.S. Production (1000 Lbs.)	837,866	893,277	912,443	924,092	939,880	944,030	947,464	946,496	946,686	945,475	945,348	944,794
U.S. Fresh Alloc. (1000 Lbs.)	694,537	718,104	732,134	741,319	753,770	757,249	760,076	759,503	759,752	758,924	758,945	758,629
U.S. Proc. Alloc (1000 Lbs.)	143,329	175,173	180,309	182,773	186,110	186,781	187,388	186,993	186,934	186,551	186,403	186,166
<b>FRESH MARKET</b>												
Domestic Production (1000 Lbs.)	694,537	718,104	732,134	741,319	753,770	757,249	760,076	759,503	759,752	758,924	758,945	758,629
Imports (1000 Lbs.)	40,719	53,157	60,879	70,751	82,126	95,235	110,341	127,749	147,809	170,925	197,562	228,258
Total Supply (1000 Lbs.)	735,256	771,261	793,013	812,069	835,896	852,484	870,417	887,252	907,561	929,849	956,507	986,887
<i>Appendix Table 2 (cont.)</i>	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>FRESH MARKET (cont.)</b>												
Exports (1000 Lbs.)	12,040	15,196	13,847	14,717	14,156	14,517	14,284	14,435	14,338	14,400	14,360	14,386
Total Utilization (1000 Lbs.)	723,216	756,065	779,166	797,353	821,740	837,966	856,133	872,817	893,223	915,449	942,147	972,501
Per Capita Fresh Demand (Lbs.)	2.61	2.71	2.77	2.81	2.87	2.91	2.95	2.98	3.03	3.08	3.14	3.21
CA Fresh Grower Price (Cents/Lb.)	138.00	132.60	134.52	136.46	138.31	140.16	142.02	143.87	145.72	147.57	149.42	151.28
PA Fresh Grower Price (Cents/Lb.)	95.20	91.04	91.58	92.19	92.84	93.50	94.18	94.87	95.56	96.26	96.95	97.65
Other U.S. Fresh Price (Cents/Lb.)	134.46	135.77	118.83	119.78	120.76	121.89	123.04	124.27	125.49	126.73	127.97	129.22
U.S. Fresh Grower Price (Cents/Lb.)	115.00	112.64	109.44	110.27	111.13	112.11	113.13	114.20	115.27	116.36	117.44	118.54
Fresh Retail Price (Cents Per Lb.)	200.79	198.43	195.23	196.05	196.92	197.90	198.91	199.99	201.05	202.15	203.23	204.32
<b>PROCESSED MARKET</b>												

<b>Domestic Production (1000 Lbs.)</b>	143,329	175,173	180,309	182,773	186,110	186,781	187,388	186,993	186,934	186,551	186,403	186,166
<b>Imports (1000 Lbs.)</b>	260,000	272,125	282,685	286,334	293,317	298,067	303,760	308,704	313,889	318,806	323,769	328,627
<b>Total Supply (1000 Lbs.)</b>	403,329	447,298	462,994	469,107	479,426	484,847	491,148	495,697	500,823	505,357	510,171	514,792
<b>Exports (1000 Lbs.)</b>	16,200	16,435	17,130	16,579	15,950	15,064	14,409	14,012	13,969	14,187	14,561	14,954
<b>Domestic Utilization (1000 Lbs.)</b>	387,129	430,863	445,865	452,528	463,477	469,783	476,739	481,685	486,853	491,170	495,610	499,838
<b>Per Capita Proc Disappearance (Lbs.)</b>	1.4	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7
<b>CA Proc Grower Price (Cents/Lb.)</b>	65.0	64.9	65.6	65.9	66.4	66.7	67.2	67.5	67.9	68.3	68.7	69.1
<b>PA Proc Grower Price (Cents/Lb.)</b>	50.8	54.1	55.7	57.0	56.1	55.3	54.7	54.7	54.7	54.7	54.5	54.3
<b>Other U.S. Proc Grower Price (Cents/Lb.)</b>	54.3	56.4	59.1	61.3	62.9	64.1	65.0	65.5	65.8	66.0	66.1	66.0
<b>U.S. Proc Grower Price (Cents Per Lb.)</b>	52.4	55.7	56.8	57.7	57.1	56.5	56.1	56.1	56.1	56.1	56.0	55.9
<b>Proc Retail Price (Cents Per Lb.)</b>	75.1	75.4	75.6	75.7	75.8	75.9	76.0	76.2	76.3	76.4	76.7	76.8
<b>Average Grower Prices (Fresh &amp; Processed)</b>												
<b>California (Cents Per Lb.)</b>	133.0	124.9	126.8	128.6	130.3	132.0	133.8	135.5	137.2	138.9	140.7	142.4
<b>Pennsylvania (Cents Per Lb.)</b>	84.9	81.5	82.4	83.1	83.4	83.7	84.0	84.5	85.1	85.6	86.0	86.5
<b>Other U.S. (Cents Per Lb.)</b>	125.7	125.7	111.2	112.3	113.4	114.6	115.7	116.8	117.9	119.0	120.1	121.2
<b>Total U.S. (Cents Per Lb.)</b>	104.3	101.5	99.0	99.9	100.4	101.1	101.8	102.7	103.6	104.5	105.3	106.2