Development of a Computer Program for Reverse Engineering an Existing Product

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SUMMARY
TechWizard™ is a computer program that uses advanced programming techniques to aid in new product formulation to achieve required sensory, quality and compositional goals (Phillips and Roland, 1999). TechWizard™ was used to develop ingredient listings and nutrition labels for an ice cream formula and a chocolate chip cookie formula. Next, the ingredient listing and nutrition label information for each formula was used to develop formulations that were as similar as possible to the original formulas. TechWizard™ proved to be an excellent tool for reverse engineering products when adequate information was provided.

INTRODUCTION
Developing a formulation to match an existing product can be a complicated process that involves meeting a variety of goals. Quickly developing a formulation that approximates an existing formula would provide tremendous benefits for consultants, regulators, product developers, those concerned with infringement issues, and others.

Objective:
The objective of this research was to develop and test a computer program (referred to as TechWizard™) to determine what information in addition to a nutrition label and ingredient listing is necessary to develop an equivalent formulation or reverse engineer a product.

MATERIAL & METHODS
Development of the TechWizard™ Computer Program

TechWizard™ was developed to provide the following components in one easy to use computer program:

- Formula & Ingredient Archiving System
- Recipe Entry & Formula Batching
- Nutrition Labeling
- Nutrition Facts Converter
- Least Cost Formulation
- Reverse Engineering

Testing Reverse Engineering with TechWizard™
Standard vanilla ice cream and chocolate chip cookie recipes (Tables 1 and 3) were analyzed using TechWizard™. The actual compositions were calculated (Tables 2 and 4) and the Nutrition Facts labels and ingredient listings produced (Figures 2 and 3). The Nutrition Facts and ingredient listings were used to reverse engineer each product using the procedure that follows (also shown in Figure 1). The composition of the reverse engineered formulas was then compared with the actual compositions.

Reverse Engineering Procedure using TechWizard™

1. TechWizard™ converted Nutrition Facts information for a serving size to composition information on 100 g basis providing ranges for the values.
2. The user selected ingredients based on the product's ingredient listing. Prices can be modified to maintain the same ingredient order as in the listing.
3. TechWizard™ determined a formula to match the composition.
4. For further iterations the user had the option to modify property ranges or to set ranges for ingredients as needed.

Figure 1. Reverse engineering with TechWizard™.

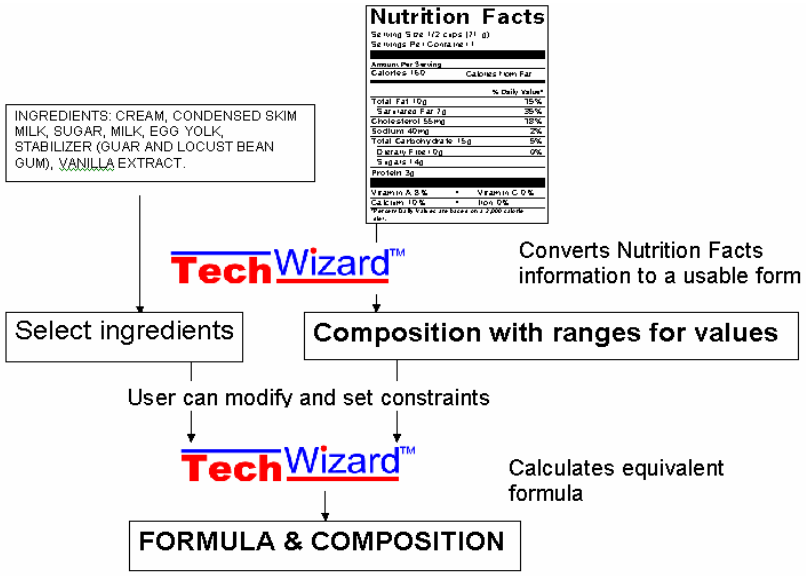


Table 1. Actual ice cream formula.

Ingredient	% (Wt./Wt.)
Cream	33.688
Condensed Skim Milk	25.091
Liquid Sugar	22.782
Milk	16.150
Egg Yolk with Sugar	1.914
Stabilizer	0.250
Vanilla	0.125
Total	100.000

Figure 2. Nutrition Facts and ingredient listing* for the ice cream.

Nutrition Facts

Serving Size 1/2 cups (71 g)
Servings Per Container 1

Amount Per Serving	
Calories 160	Calories from Fat 90
	% Daily Value*
Total Fat 10g	**15%**
Saturated Fat 7g	**35%**
Cholesterol 55mg	**18%**
Sodium 40mg	**2%**
Total Carbohydrate 15g	**5%**
Dietary Fiber 0g	**0%**
Sugars 14g	
Protein 3g	

Vitamin A 8%	•	Vitamin C 0%
Calcium 10%	•	Iron 0%

*Percent Daily Values are based on a 2,000 calorie diet.

INGREDIENTS: CREAM, CONDENSED SKIM MILK, SUGAR, MILK, EGG YOLK, STABILIZER (GUAR AND LOCUST BEAN GUM), VANILLA EXTRACT.

*Created with TechWizard™.

Table 2. Actual ice cream composition.

Property	Composition
Calories (cal/100g)	229.45
Fat Calories (cal/100g)	130.39
Total Fat (g/100g)	14.49
Saturated Fat (g/100g)	9.53
Cholesterol (mg/100g)	79.57
Sodium (mg/100g)	58.00
Total Carb. (g/100g)	20.48
Sugars (g/100g)	20.32
Protein (g/100g)	4.25
Total Solids (%)	40.08
Vitamin A (IU/100g)	555.06
Vitamin C (mg/100g)	1.00
Calcium (mg/100g)	127.17
Iron (mg/100g)	0.11
Egg Yolk Solids (%)	0.75
Milkfat (%)	14.00
MSNF (%)	10.00
Sucrose (%)	15.00
Stabilizer (%)	0.25

Table 3. Actual chocolate chip cookie formula.

Ingredient	% (Wt./Wt.)
Wheat Flour	27.385
Chocolate Chips	23.473
Brown Sugar	18.583
Butter	9.780
Shortening	7.824
Eggs	5.868
Corn Syrup	3.912
Vanilla	1.794
Baking Powder	0.690
Salt	0.690
Total	100.000

Figure 3. Nutrition Facts and ingredient listing* for baked chocolate chip cookie.

Nutrition Facts

Serving Size 1 Cookie (30 g)
Servings Per Container 1

Amount Per Serving	
Calories 150	Calories from Fat 70
	% Daily Value*
Total Fat 8g	**12%**
Saturated Fat 3.5g	**18%**
Cholesterol 20mg	**7%**
Sodium 150mg	**6%**
Total Carbohydrate 18g	**6%**
Dietary Fiber 0g	**0%**
Sugars 6g	
Protein 2g	

Vitamin A 2%	•	Vitamin C 0%
Calcium 4%	•	Iron 4%

*Percent Daily Values are based on a 2,000 calorie diet.

INGREDIENTS: ENRICHED WHEAT FLOUR (UNBLEACHED HARD WHEAT FLOUR, MALTED BARLEY FLOUR, NIACIN, REDUCED IRON, THIAMIN MONONITRATE, RIBOFLAVIN, FOLIC ACID), MILK CHOCOLATE CHIPS (SUGAR, CHOCOLATE, COCOA BUTTER, MILK, MILK FAT, SOY LECITHIN, VANILLIN), BROWN SUGAR, BUTTER, VEGETABLE SHORTENING (PARTIALLY HYDROGENATED SOYBEAN AND COTTONSEED OIL, MONO AND DIGLYCERIDES), EGGS, CORN SYRUP, VANILLA EXTRACT, BAKING POWDER (CALCIUM ACID PHOSPHATE, BICARBONATE OF SODA, CORNSTARCH), SALT.

*Created with TechWizard™.

Table 4. Actual chocolate chip cookie composition.

Property	Dough	After Baking*
Calories (cal/100g)	456.669	485.025
Fat Calories (cal/100g)	212.644	225.848
Total Fat (g/100g)	23.886	25.369
Saturated Fat (g/100g)	11.471	12.183
Cholesterol (mg/100g)	58.741	62.388
Sodium (mg/100g)	465.189	494.074
Total Carb. (g/100g)	56.677	60.196
Dietary Fiber (g/100g)	1.539	1.539
Sugars (g/100g)	19.785	21.013
Protein (g/100g)	5.244	5.570
Total Solids (%)	88.561	94.060
Vitamin A (IU/100g)	450.427	478.395
Vitamin C (mg/100g)	0.094	0.100
Calcium (mg/100g)	111.030	117.924
Iron (mg/100g)	2.168	2.303

* 5.5% moisture loss during baking

RESULTS & DISCUSSION

Reverse Engineering the Ice Cream

The composition ranges derived from the Nutrition Facts information for a 71 g serving encompassed the actual amounts except for Vitamin C and Iron (Table 5). Ingredient prices were assigned in descending amounts. These specifications were used to formulate an equivalent recipe for the ice cream using TechWizard™ (first calculation in Table 6). The composition of that equivalent recipe (first calculation) is shown in Table 7. Although the first calculation provided a formula that met compositional requirements, stabilizer and vanilla were not used. Standard amounts for stabilizer and vanilla were specified and another best-fit formula was derived (second calculation in Tables 6 and 7). This formula was low in egg yolk since other ingredients provided the required composition. The user could adjust this by increasing the specified range for the ingredient. Overall the second attempt produced a prototype formula that closely resembled the original ice cream formula (Figure 4).

Table 5. Composition of the actual ice cream and composition calculated from its Nutrition Facts for a 71 g serving.

Property	Actual	Based on Nutrition Facts (71 g)			
		Calculated	Lower Range	Upper Range	Range + / - (%)
Calories (cal/100g)	229.45	225.35	202.815	247.885	10
Fat Calories (cal/100g)	130.39	126.77	114.093	139.447	10
Total Fat (g/100g)	14.49	14.09	13.386	14.795	5
Saturated Fat (g/100g)	9.53	9.86	9.367	10.353	5
Cholesterol (mg/100g)	79.57	77.47	69.723	85.217	10
Sodium (mg/100g)	58.00	56.34	53.523	59.157	5
Total Carb. (g/100g)	20.48	21.13	20.074	22.187	5
Sugars (g/100g)	20.32	19.72	18.734	20.706	5
Protein (g/100g)	4.25	4.23	4.019	4.442	5
Total Solids (%)	40.08	39.60	37.620	41.580	5
Vitamin A (IU/100g)	555.06	563.40	507.060	619.740	10
Vitamin C (mg/100g)	1.00	0.00	0.000	0.000	10
Calcium (mg/100g)	127.17	140.80	126.720	154.880	10
Iron (mg/100g)	0.11	0.00	0.000	0.000	10
Egg Yolk Solids (%)	0.75				
Milkfat (%)	14.00				
MSNF (%)	10.00				
Sucrose (%)	15.00				
Stabilizer (%)	0.25				

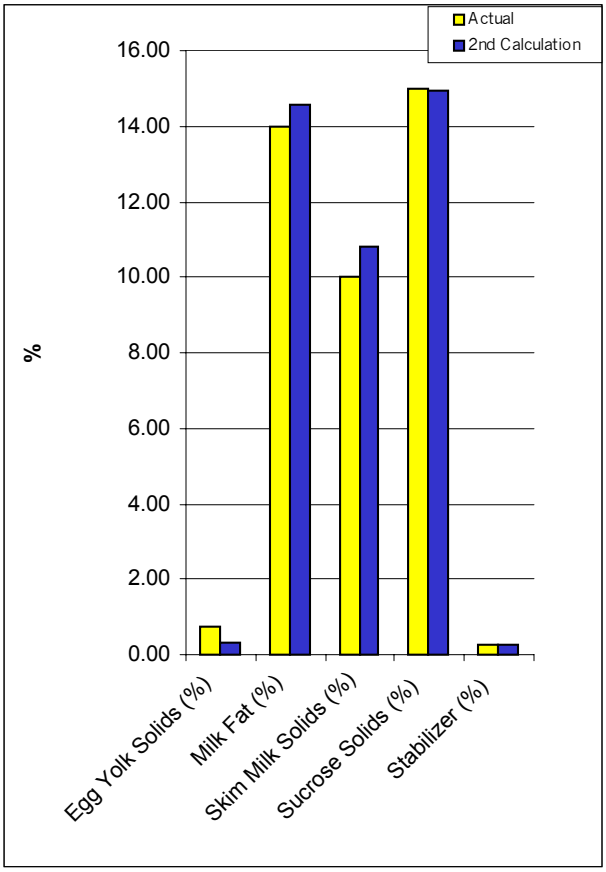
Table 6. Ice cream formula after each TechWizard™ reverse engineering calculation.

		First	Second
Ingredient	Actual	Calculation	Calculation
	%	%	%
Cream	33.688	35.500	35.540
Condensed Skim Milk	25.091	29.299	29.426
Liquid Sugar	22.782	22.912	22.860
Milk	16.150	11.432	10.943
Egg Yolk with Sugar	1.914	0.857	0.857
Stabilizer	0.250	0.000	0.250
Vanilla	0.125	0.000	0.125
Total	100.000	100.000	100.000

Table 7. Ice cream composition after each TechWizard™ reverse engineering calculation.

Property	Actual Composition	First Calculation	Second Calculation
Calories (cal/100g)	229.45	233.653	234.46
Fat Calories (cal/100g)	130.39	133.11	133.11
Total Fat (g/100g)	14.49	14.79	14.79
Saturated Fat (g/100g)	9.53	9.829	9.83
Cholesterol (mg/100g)	79.57	69.72	69.72
Sodium (mg/100g)	58.00	56.91	61.66
Total Carb. (g/100g)	20.48	20.70	20.86
Sugars (g/100g)	20.32	20.70	20.70
Protein (g/100g)	4.25	4.44	4.44
Total Solids (%)	40.08	40.71	40.99
Vitamin A (IU/100g)	555.06	561.55	561.55
Vitamin C (mg/100g)	1.00	1.08	1.08
Calcium (mg/100g)	127.17	136.04	136.21
Iron (mg/100g)	0.11	0.07	0.07
Egg Yolk Solids (%)	0.75	0.34	0.34
Milkfat (%)	14.00	14.57	14.57
MSNF (%)	10.00	10.82	10.82
Sucrose (%)	15.00	14.98	14.95
Stabilizer (%)	0.25	0.00	0.25

Figure 4. Comparison of actual ice cream composition with the second Techwizard™ reverse engineering calculation.



Reverse Engineering the Cookie

Due to the small serving size (30 g) wider ranges were used to derive a composition from the Nutrition Facts information (Table 8). Even so the calculated composition and ranges for % protein did not encompass the actual value. The cookie dough composition was calculated based on 5.5% moisture loss for the cookie product.

The first calculation provided a formula that met the compositional requirements, although the ingredients vanilla, baking powder and salt were not used (Table 9 and 10).

The second calculation included standard usage levels for vanilla, baking powder, and salt. The usage level for chocolate chips was estimated by drying and weighing the chips after the baked dough was dissolved in cold water. This yielded a formula that better represented the ingredient listing, however, corn syrup was not used (Table 9 and 10).

A recommended amount for corn syrup was imposed for the third calculation. Since the ingredient corn syrup falls between eggs and vanilla in the listing, its recommended usage range was set to between 1.75 and 3.5. This yielded a formula that better represented the ingredient listing and composition of the original cookie (Table 9 and 10).

Since the estimated protein composition range did not encompass the actual value, a fourth calculation was made using the results from a protein analysis. The resulting formula most closely matched the composition of the original cookie (Figure 5, See page 6).

Table 8. Composition of actual chocolate chip cookie dough* and composition calculated from its Nutrition Facts for a 30 g serving .

Property	Actual	Based on Nutrition Facts (30g)			
		Calculated	Lower Range	Upper Range	Range + / - (%)
Calories (cal/100g)	456.669	470.810	400.190	541.430	15
Fat Calories (cal/100g)	212.644	225.990	192.090	259.890	15
Total Fat (g/100g)	23.886	25.110	22.600	27.620	10
Saturated Fat (g/100g)	11.471	10.990	9.890	12.080	10
Cholesterol (mg/100g)	58.741	62.780	56.500	69.050	10
Sodium (mg/100g)	465.189	470.810	423.730	517.890	10
Total Carb. (g/100g)	56.677	56.500	50.850	62.150	10
Dietary Fiber (g/100g)	1.539	0.000	0.000	0.000	10
Sugars (g/100g)	19.785	18.830	16.950	20.720	10
Protein (g/100g)	5.244	6.280	5.650	6.910	10
Total Solids (%)	88.561	88.500	79.630	97.330	10
Vitamin A (IU/100g)	450.427	313.90	266.79	360.95	15
Vitamin C (mg/100g)	0.094	0.00	0.00	0.00	15
Calcium (mg/100g)	111.030	125.50	106.72	144.38	15
Iron (mg/100g)	2.168	2.30	1.92	2.60	15

* 5.5% moisture loss during baking

Table 9. Chocolate chip cookie dough formula after each TechWizard™ reverse engineering calculation.

		First	Second	Third	Fourth
Ingredient	Actual	Calculation	Calculation	Calculation	Calculation
	%	**%**	**%**	**%**	**%**
Wheat Flour	27.385	54.938	38.378	37.148	28.878
Choc. Chips	23.473	0.000	20.000	20.000	23.000
Brown Sugar	18.583	17.398	16.946	16.413	20.290
Butter	9.780	21.414	14.173	14.169	11.486
Shortening	7.824	4.498	4.160	4.175	7.299
Eggs	5.868	1.753	3.843	3.845	4.797
Corn Syrup	3.912	0.000	0.000	1.750	1.750
Vanilla	1.794	0.000	1.500	1.500	1.500
Baking Powder	0.690	0.000	0.500	0.500	0.500
Salt	0.690	0.000	0.500	0.500	0.500
Total	100.000	100.000	100.000	100.000	100.000

Table 10. Chocolate chip cookie dough composition after each TechWizard™ reverse engineering calculation.

	Actual	**1st**	**2nd**	**3rd**	**4th**
Property	**Composition**	**Calc.**	**Calc.**	**Calc.**	**Calc.**
Calories (cal/100g)	456.67	464.98	457.43	455.99	465.25
Fat Calories (cal/100g)	212.64	203.06	201.32	201.33	218.15
Total Fat (g/100g)	23.89	22.60	22.60	22.60	24.49
Saturated Fat (g/100g)	11.47	12.08	12.08	12.08	12.08
Cholesterol (mg/100g)	58.74	56.50	56.50	56.50	56.50
Sodium (mg/100g)	465.19	187.18	395.81	397.67	380.63
Total Carb. (g/100g)	56.68	58.89	58.26	58.14	57.39
Dietary Fiber (g/100g)	1.54	1.48	1.72	1.68	1.56
Sugars (g/100g)	19.79	16.95	16.95	16.95	20.72
Protein (g/100g)	5.24	6.07	5.93	5.81	5.25
Total Solids (%)	88.56	88.47	89.15	88.91	89.51
Vitamin A (IU/100g)	450.43	687.06	541.08	541.00	482.01
Vitamin C (mg/100g)	0.09	0.00	0.08	0.08	0.09
Calcium (mg/100g)	111.03	29.15	93.30	92.71	100.38
Iron (mg/100g)	2.17	2.95	2.54	2.47	2.22

Calc - calculation

CONCLUSIONS

Adequate serving size is needed to calculate a representative composition from the Nutrition Facts information. The 71 g ice cream serving size was adequate while the 30 g cookie serving size was too small to provide a representative composition.

The user needs to enter a recommended range for ingredients that do not contribute significantly to the nutritional composition of the product (flavorings, stabilizer) or do not contribute a unique property (the protein and cholesterol of egg yolk is considered equivalent to the protein and cholesterol of milk ingredients).

Prices can be modified to maintain the same ingredient order as in the ingredient listing.

TechWizard™ proved to be an excellent tool for reverse engineering products when adequate information was provided.

REFERENCES

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Roland, A.M, L. G. Phillips, and K.J. Boor, 1999. Effects of fat replacers on the sensory properties, color, melting, and hardness of ice cream. J Dairy Sci. 82:2094-2100.

Figure 5. Comparison of actual cookie dough composition with the Techwizard™ reverse engineering calculations.