

Comparison of consistency, solubility, and texture of foods to determine choking risk: a novel method and single-lab validation study

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Abstract

As part of routine sample screening, the FDA evaluates foods for choking hazards. Choking hazards can come from the inherent properties of foods, such as pits remaining in fruits, or from extraneous filth elements, such as stones or pieces of plastic. While evaluation of risk for choking hazards can vary on a case-by-case basis, several physical properties are typically assessed when determining choking risk: size, shape, consistency, and texture.

In this study, a method was developed to measure these attributes and a single-lab validation using jelly mini-cup candies was performed as a case study. Three analysts participated in the validation. Measurements of physical dimensions, solubility, consistency, and texture were evaluated using 95% confidence intervals and results were consistent in all cases.

Key Words: Filth, Choking, Import Alert

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Introduction

Food-related choking risk is a major cause of death among infants and toddlers and has been identified as a relevant public health challenge (1). Choking on food is an even greater threat to

the safety of adults aged 65 and older, where deaths averaged more than 500 individuals between the years of 2007 to 2010 in the United States, which represents a mortality rate about seven times higher than that of infants and toddlers (2). Accordingly, the U.S. Food and Drug Administration (FDA) routinely monitors foods to assess choking risk.

International guidelines state that size, shape, and texture are the most important attributes of a food when evaluating potential for choking risk. Small and large food items can both be dangerous, with smaller items more likely to prematurely lodge in the airway and larger items more difficult to move around in the mouth. Items that are round or cylindrical in shape are the most likely to become lodged in the airway and present a particularly high risk of choking. Objects that have a hard, sticky, fibrous or compressible texture are also particularly dangerous (1).

Currently, routine analyses for choking hazards in foods at the FDA are focused on hard and sharp objects, such as seeds or pits in fruits or glass and plastic contaminants (3). However, there is a need for a method to test a wider range of food types for choking risk, including softer, more pliable foods. One example of a soft food that may pose a choking risk are jelly mini-cup candies. These candies are typically packaged as individual mouth-sized servings and may contain fruit pieces, spices, or other additives (Figure 1). The candies are designed to be transferred from a plastic cup into the mouth whole (7, 8) and are primarily imported into the United States from east Asia (6).

In August 2001, the U.S. Food and Drug Administration (FDA) issued a warning to notify the public that jelly mini-cup candies containing konjac, a glucomannan, pose a choking hazard risk. This warning was primarily due to the choking deaths of six children in the United States (6, 7). Following consultation with experts at the Consumer Product Safety Commission (CPSC), the FDA issued an additional warning, and later, issued Import Alert 33-15 "Detention Without Physical Examination of Gel Candies Containing Konjac" (8). The alert outlines the physical characteristics that led to the choking hazard, though no specific regulatory limits have yet been adopted by the FDA.

In recent years, jelly mini-cup candy manufacturers have reformulated their products to replace konjac with alternative gel forming ingredients such as carrageenan, seaweed extract, and various plant gums, which showed slightly higher solubility and easier penetration (5). However, the European Food Safety Authority (EFSA) has determined that the non-konjac gel forming ingredients can also give rise to the formation of firm gels that do not solubilize and were also likely to pose a choking risk (9). To evaluate whether these new jelly mini-cup candies containing alternative gel-forming ingredients pose a choking risk and may require FDA regulation, a method that can provide information on candy size, shape, consistency, and texture is needed.

In the present study, jelly mini-cup candies were used as a case study to develop a method to collect data relevant to the assessment of food choking risk. Specifically, the present study collected data on candy size by measuring candies while inside and after removal from candy

cups, qualitatively described candy shape, measured candy consistency with a compressibility test and evaluated texture by assessing slipperiness. Results of a single-lab validation are presented and standards for determining choking risk from other organizations are discussed based on study results. This information can be used by FDA experts to define criteria that can be used in evaluating these candies for choking risk. The method laid out below is a modification of a previously published jelly mini-cup candy method (5).

Materials and Methods

Equipment

Graduated cylinder, Class A, at least 100 mL
Glass beakers, 600 mL
Digital camera
Certified digital calipers (Mitutoyo, ABS Digimatic Caliper)
Shaker incubator (New Brunswick Scientific, C24 Incubator Shaker)
Top-loading balance (Mettler-Toledo, Adventurer Pro AV3102C)
Paper towels
3-inch (7.62 cm) US standard testing sieve pan (Humboldt Mfg.)
70-mm filter paper circles (Whatman)
Benchtop testing machine (1ST Tinius Olsen, with 100-N load cell)
Friction ramp apparatus for benchtop testing machine (Tinius Olsen)

Reagents

NaOH (Supelco, Cat. No. 1.06462.1000)
NaCl (Fisher, Cat. No. BP358-1)
KCl (Fisher, Cat. No. BP366-1)
Na₂SO₄ (Fisher, Cat. No. S419-500)
NH₄Cl (Fisher, Cat. No. A661-500)
Urea (Fisher, Cat. No. U15-500)
Lactic Acid (Acros Organics, Cat. No. 41296-5000)
Salivary α -amylase (MP Biomedicals, Cat. No. 100447)
Artificial Saliva Solution (Supplement 2)

Procedure

Morphological Description

1. Take a picture of a candy showing the overall shape, with a ruler in the photograph for scale. Describe the shape to aid in interpretation of the photograph.
2. Obtain 1 jelly mini-cup candy from each of the 6 subsamples, for a total of 6 candies.
3. Take 1 candy and using calibrated calipers, measure the height, maximum diameter, and minimum diameter for each candy while still in its original plastic cup. Measure the lip of the plastic cup. Record the measured dimensions in mm after subtracting the lip thickness from the diameter measurements and half the lip thickness from the height measurement. Repeat for the remaining 5 candies.
4. Measure the height, maximum diameter, and minimum diameter of the same 6 candies once they are removed from their plastic cup. Record the measurements.

Solubility

1. Obtain 6 new candies, one from each subsample. Obtain 6 600-mL beakers.
2. Remove 1 candy from its container and blot off excess moisture with paper towels.
3. Place 1 beaker on a balance and tare.
4. Place the blotted candy into the beaker and record the mass.
5. Repeat steps 2-4 for each of the remaining 5 candies.
6. Add 58 mg of α -amylase to each beaker and 200 mL of artificial saliva, pre-heated to 37 °C.
7. Place beakers in a shaker incubator, pre-heated to 37 °C, and shake contents at about 50 rpm for 30 min.
8. Remove beakers and pour out artificial saliva solution, using fingers or a #140 sieve to retain the candy in the beaker.
9. Remove candy from beaker and blot off excess moisture.
10. Place beaker on balance and tare. Add blotted candy to beaker and record the mass of the candy.

Consistency

1. Obtain 6 new candies, one from each subsample.
2. Remove each candy from its container and remove liquid from exterior of candies with paper towels to avoid slipping of candy during testing process.
3. Place 1 candy into a 3-inch (7.62 mm) US standard testing sieve pan, containing a 70-mm filter paper circle on the bottom to prevent slipping of candy, and place the pan onto the bottom testing-machine patten. Ensure that the candy itself is centered under the upper patten.
4. Test the candy to determine breaking strength in newtons using the appropriate method for your testing machine. Compress candy along its longest axis unless candy shape prevents this. Record the result.
5. Repeat steps 2-4 for the remaining candies.

Texture

1. Remove one jelly mini-cup candy from its packaging for each of six subsamples. Do not remove excess liquid from candy since the friction measurement is meant to reflect slipperiness as it enters a potential consumer's mouth as typically eaten.
2. Analyze individual samples using a friction measuring attachment on a benchtop testing machine. Use a pull length of 100 mm at a rate of 100 mm/min until completion. Record static and kinematic coefficient friction measurements.
3. If the candy is too slippery to obtain coefficient of friction measurements, record this.

Single-Lab Validation

Nine different candy samples were obtained to represent a variety of formulations and included samples from 8 distributors, 8 brands, 4 countries of origin, and 5 different gel-forming ingredients, including konjac (Table 1). Samples also included candies with and without fruit inside. Gelatin control samples were obtained as both a dry mix and as a premade retail gelatin cup. Prior to analyses, the dry mix was prepared according to manufacturer's instructions for finger-type gelatin in plastic jelly-candy cups from which the original candy had been removed.

Three analysts from the Atlanta Human and Animal Food Laboratory participated in the single-lab validation. One analyst performed analyses on 10 candy samples, with each test (dimensions, solubility, consistency, texture) containing 5 independent replicates. The resulting data were used for baseline measurements and to make general observations about candies. Two additional analysts each performed tests on 5 random samples, with each test containing 3 replicates. In total, 320 candies were measured. Each of the runs were performed in random order and at different times to reduce time dependency on results.

To determine baseline, mean values for dimensional change, solubility, and consistency, measurements from a single analyst were analyzed since the additional analysts did not measure all candy varieties. Mean percent change in candy dimensions in and out of plastic cups and compression force between samples were analyzed using Welch's ANOVA to account for heterogeneity in sample variances (10) and data were plotted. Dissolution measurements were plotted to show trends in solubility. Analyses were performed using R version 4.2.1 (11) with the Hmisc (12), rstatix (13), and plotrix (14) packages. To test for between-analyst differences in measured values for dimension, solubility, and consistency, 95% confidence intervals, assuming normally distributed data, were calculated using the t.test function in base R.

Results

Baseline measurements

The greatest mean diameter of any jelly mini-cup candy inside of a plastic cup was 48.14 mm (SD = 0.29 mm) which increased to 50.98 mm (SD = 1.92 mm) outside of a cup. The smallest mean diameter of any candy was 14.26 mm (SD = 0.13 mm) inside of a cup and 13.39 mm (SD = 0.49 mm) outside. For control gelatin, the greatest diameter was 58.69 mm (SD = 0.81 mm) inside of a cup and 59.70 mm (SD = 2.64 mm) outside. The smallest diameter inside a cup was 35.46 mm (SD = 0.27 mm) and 32.11 mm (SD = 1.0 mm) outside. Measurements of candy before and after removal from plastic cups is a measurement of consistency and it is important to know how much candy dimension and shape changes following removal from a cup to evaluate choking risk. In order to simplify comparison between candies, a single metric of size change was calculated. The metric was the percent change in candy size for height, minimum and maximum diameter averaged to find a single overall percent change value for each of the 10 candy types, hereafter referred to as overall percent change. The overall percent change in candy size when measured inside of the cups versus outside ranged from an overall mean change of 2.7% to 9.5%, which corresponded to an overall range in change of dimensional measure of between 0.7 mm to 3.6 mm. The greatest percent change in any single dimension of any individual candy piece was 19.5%, which corresponded to a change of 3.6 mm in maximum diameter in sample 4. The greatest single dimensional change of any individual candy piece was 8.0 mm, which was a 17.2% change in maximum diameter in sample 8. The mean overall percent change between candies was marginally significant (Welch's ANOVA; $F_{11.0, 18.8} = 2.9$, $p = 0.02$), with sample 7 showing the least change, though the Games-Howell pairwise test showed no significant results. Gelatin control sample results were comparable to jelly-cup candy results (Figure 2).

Solubility of candies was generally low, with 8 of 10 candy samples showing an increase in mass following the solubility procedure. The gain in mass for these 8 samples ranged from 1.0% to 3.5% of the original candy mass. Two of the candies lost mass: sample 8 lost an average of 8.1% of its original mass and sample 9 lost an average of 3% of its original mass. All candies remained self-supporting following dissolution trials. Gelatin controls completely dissolved in ca. 20 minutes (Figure 3).

Mean candy consistency varied between samples (Welch's ANOVA; $F_{11.0, 18.2} = 78.5$, $p = 5.5 \times 10^{-13}$). Sample 4 required the lowest mean break force 4.6 N (SD = 0.79 N) and the konjac sample the highest, 33.8 N (SD = 4.1 N). The lab prepared gelatin control required a comparable mean break force to candy samples, 16.7 N (SD = 2.3 N), while the pre-made control required the lowest mean break force overall, 4.0 N (SD = 0.33 N; Figure 4, Table 2).

Candy textural slipperiness could not be measured for the 10 candies, nor for the pre-made control gelatin because the coefficient of friction was below the limit of detection for the testing machine load cells available for the lab model. The finger gelatin that was prepared in lab had a mean mass of 28.1 g (SD = 0.92 g), a mean static coefficient of friction of 0.266 (SD = 0.11) and a mean kinematic coefficient of friction of 0.42 (SD = 0.055).

Single-lab validation

Overall, 95% confidence intervals did not support significant differences between analysts in dimension, solubility, or consistency measurements (Tables 3-5). The properties of the product prevented analysts from obtaining friction measurements to determine slipperiness of texture.

Discussion

An effective method to determine consistency, size, shape, and texture of foods using jelly mini-cup candies was developed. The single-lab validation showed consistent results for analysts in all measurements, supporting the ruggedness of this method. This method will be useful in collecting data to assess choking risk of soft foods at regulatory labs, such as jelly mini-cup candies. Jelly mini-cup candies and gelatin control measurements outside the cup showed greater variances than measurements of candies taken while the candy was still inside the cup. Replicate measurements of a single type of product in a cup by a single analyst had a single standard deviation of less than 1 mm while measurements of a product outside the cup had a single standard deviation of as much as 3 mm (data not shown). This increase in variance of candy outside the cup shows a flexibility in unsupported candy. The difference in measurements of candies in and out of the cup of the sample product between analysts showed similar trends and were not significantly different ($p > 0.05$).

Solubility of candies was generally low, with only two brands showing any dissolution, while gelatin controls completely dissolved. Overall, candy mass slightly increased after being immersed in artificial saliva solution, suggesting hydration of the candies. Lack of solubility in konjac jelly-cup candies is one reason for the initial restriction in the United States and ban on the candies in Europe (5, 15), and solubility between konjac candy and candies with substitute gel-forming ingredients was comparable (Fig. 2) in this study. Two jelly-cup candies did show some dissolution, though dissolution averaged less than 10% of the initial mass. Each of the candies that showed dissolution contained seaweed extract as their sole gelling agent. Gelatin controls both completely dissolved in about 20 minutes.

Preliminary trials were performed in the dissolution study with artificial saliva containing α -amylase and not. The addition of the enzyme made no difference in dissolution, suggesting the gel forming-ingredients in jelly-cup candies are not digested by this enzyme. Gelatin candies were not included in these preliminary trials.

Compression of candies to measure consistency revealed several significant differences ($p < 0.05$). The candy with the highest breaking strength contained konjac and took at least twice the force to break (mean = 33.8 N) versus the reformulated candies (overall mean = 11.7 N) and the finger gelatin (mean = 16.7 N). The reformulated candy with the lowest required breaking force was sample 4, which contained carrageenan as its gelling polysaccharide, and the smallest physical dimensions. The pre-made gelatin had the overall lowest mean break force (4.0 N), which had a comparable mean breaking strength to sample 4 (4.6 N).

Qualitative observation suggested that presence of fruit inside the jelly-cup candies also affected breaking strength. It was observed that under load, candies often began to break at a candy-fruit interface, and that candies with fruit near the surface appeared to break more easily. It follows that candies containing a greater number of fruit pieces would also break with less force. It was also observed that the gelatin samples broke more catastrophically. That is, jelly-cups tended to break internally and flatten out, but remain intact as a single piece once broken, whereas gelatin samples often fully split into multiple pieces.

Determining coefficient of friction for the samples proved difficult because the friction level was below the limit of detection for our benchtop testing machine but may be possible with other foods. Qualitatively, however, it was observed that the fluid around the jelly-cup candy was the source of slipperiness, and that candies that were completely dried off were much less slippery. Candies were not measured without fluid because consumers are unlikely to dry candies before eating them. Gelatin candies had no fluid around them and were measured once a small amount of artificial saliva was first applied to simulate consumption (without added saliva, the dry gelatin candies adhered to the friction apparatus making it difficult to measure friction). However, the measurements were likely higher than would be seen when consuming the candies since the artificial saliva lacked mucus.

Overall, dimensions between candies varied, and ranged from a minimum mean diameter of 13.39 mm to a maximum mean diameter of 50.98 mm. Jelly-cup candies showed low solubility in an artificial saliva medium. Only candies with seaweed extract (samples 8 and 9) as the gelling agent, a less refined carrageenan product (16), and control gelatin samples showed dissolution, but all candies remained self-supporting. Reformulated candies had a consistency that showed higher compressibility than premade retail gelatin cups, but lower compressibility than konjac-containing candies. All candies were qualitatively more slippery in texture than the gelatin controls.

To date, the FDA has not adopted guidelines that can be used to determine choking risk of soft foods like jelly mini-cup candies. However, guidance used to assess the choking risk of small parts, such as toys and published opinions could be used to help the FDA to formulate its own guidelines. The U.S. Consumer Product Safety Commission website states “any object that fits, without compressing and in any orientation, entirely into the small parts cylinder” constitutes a choking risk (17, 18). The small parts cylinder has a maximum opening of 31.7 mm, which is large enough to fit all jelly mini-cup candies tested in the current study in at least one orientation. Therefore, by this standard, all tested candies represent a choking risk. Alternatively, Walker et al. (5) suggested a more comprehensive set of standards to assess choking risk of jelly mini-cup candies: “If it has a slippery surface and does not dissolve in artificial saliva in 2 min and is self-supporting before and after the solubility test, and fits into a small parts cylinder in any attitude, then it can be regarded as a choking risk.” By this more comprehensive standard, the tested jelly mini-cup candies would still all represent a choking risk, while the pre-made gelatin control would not under either standard. It remains to be seen if the standards adopted by the FDA classify jelly mini-cup candies or other soft foods as a

choking risk. It may be necessary to collect data on a wider range of foods before developing wide-ranging, comprehensive standards that define choking hazards.

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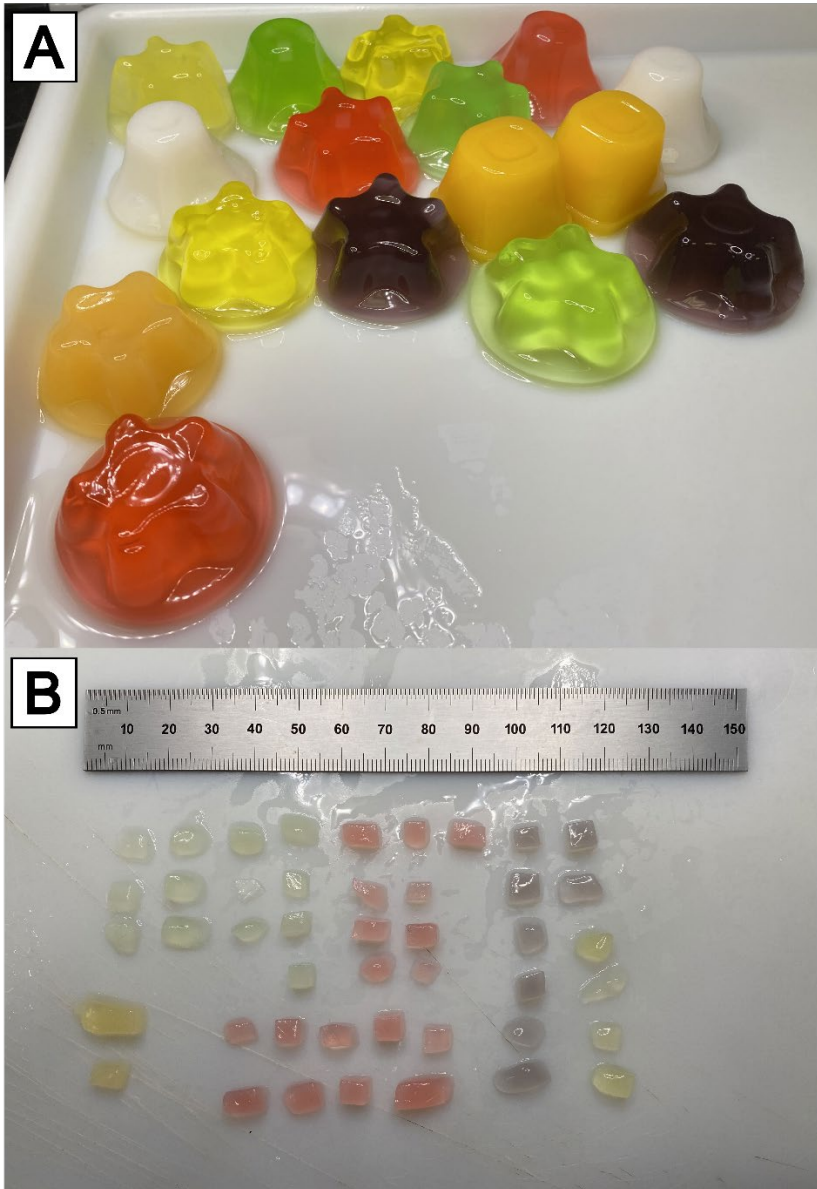


Figure 1. Example of analyzed product. A) Example jelly mini-cup candies of different types removed from containers. B) Example fruit pieces found inside some of the candies.

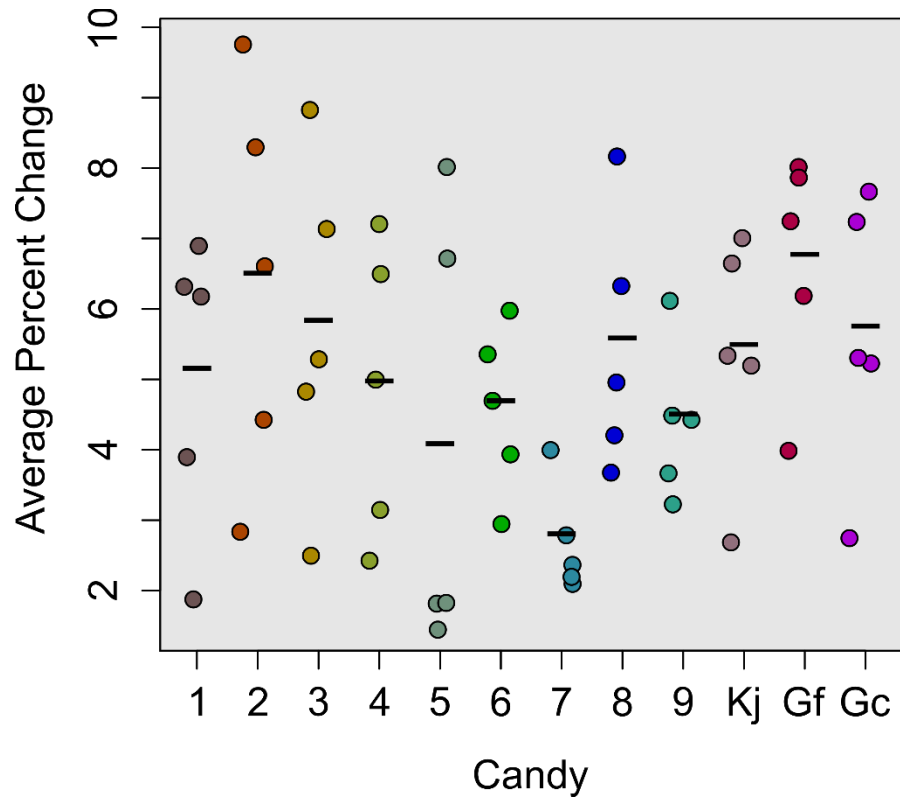


Figure 2. Jitter plot showing change in dimensions of candy when removed from container.

Jelly candy ($n = 5$ per treatment) lengths, maximum diameters and minimum diameters were measured while still inside original plastic cups and again after being removed. The average of the change in the three values was plotted for each sample. Candy containing konjac (Kj), finger gelatin (Gf) and pre-made gelatin in a cup (Gc) were used as controls. Black bars represent group means.

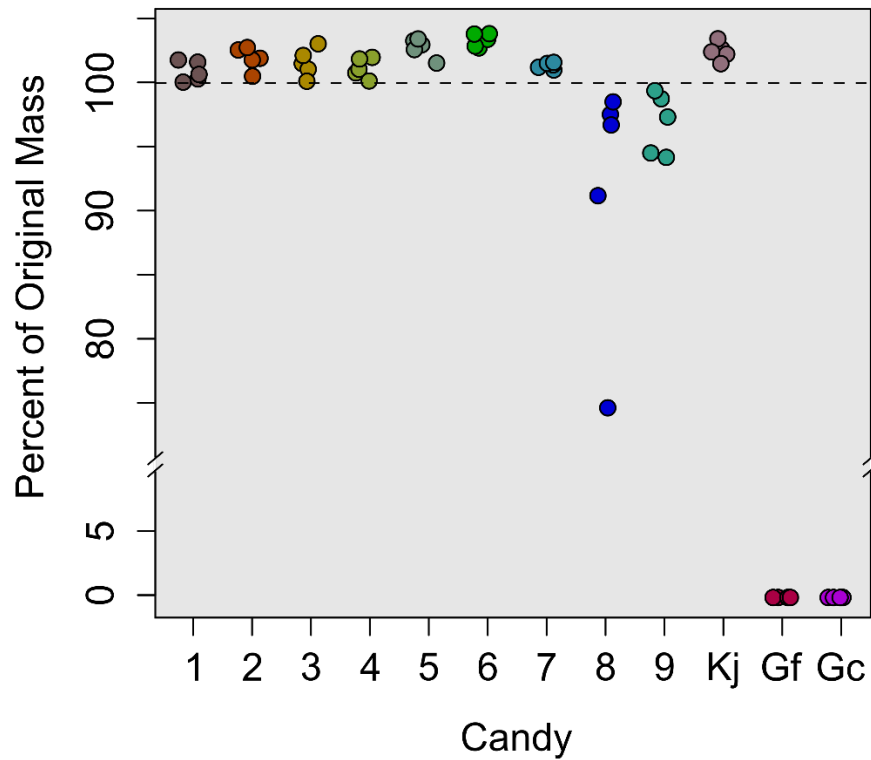


Figure 3. Jitter plot showing dissolution of candy samples. Samples (n = 5 per treatment) were removed from containers and their initial masses were recorded. Samples were submerged in an artificial saliva solution with gentle shaking for 30 minutes and 37°C, and the final masses were measured. The percent of the original mass was plotted for each sample. Candy containing konjac (Kj), finger gelatin (Gf) and pre-made gelatin in a cup (Gc) were used as controls. The dotted line represents no change in mass. Samples above the line gained mass while samples below the line showed dissolution.

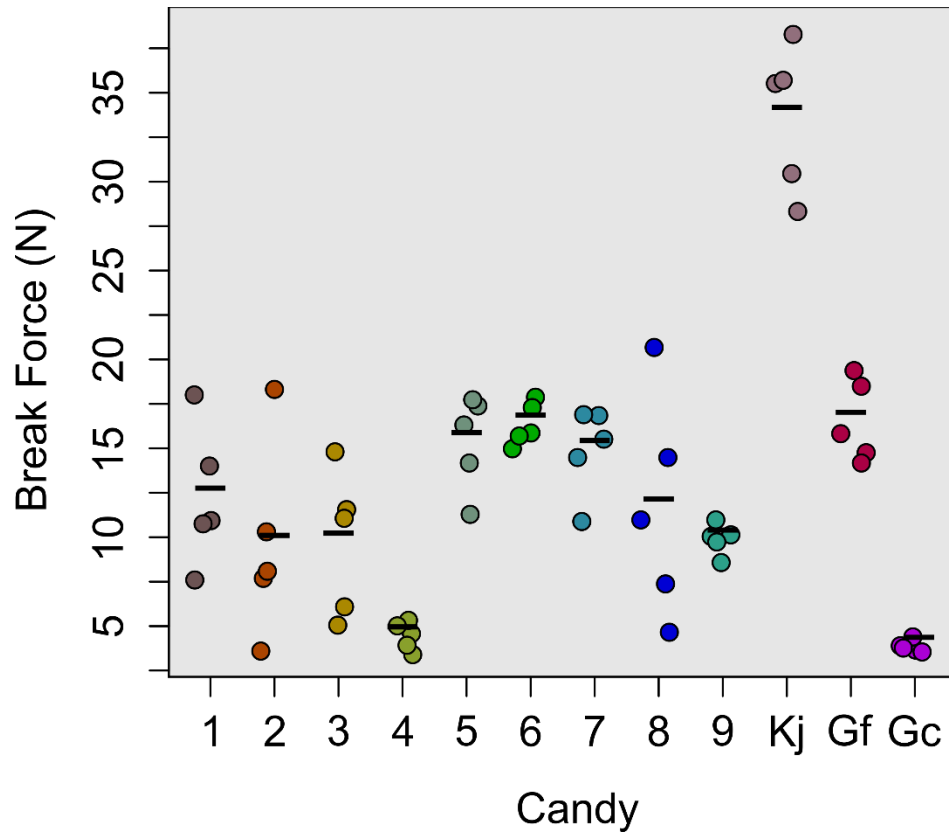


Figure 4. Jitter plot showing breaking force (N) of candy samples. Compressive force was applied to jelly candy samples ($n = 5$ per treatment) until the breaking force was reached to assess consistency of candies. Candy containing konjac (Kj), finger gelatin (Gf) and pre-made gelatin in a cup (Gc) were used as controls. Black bars represent group means.

Table 1. Gelling agents in jelly mini-cup samples listed in order of appearance in product labeling

Sample	Gelling Agent(s)
1	Carrageenan, xanthan gum, locust bean gum
2	Carrageenan, xanthan gum, locust bean gum
3	Carrageenan, xanthan gum, locust bean gum
4	Carrageenan
5	Carrageenan, locust bean gum
6	Carrageenan, locust bean gum
7	Locust bean gum, carrageenan, xanthan gum
8	Seaweed extract
9	Seaweed extract
Kj	Konjac flour

Table 2. Pairwise significance of breaking force (N) between candies and controls

Sample	1	2	3	4	5	6	7	8	9	Kj	Gf
Kj	***	**	***	***	**	**	**	**	**		
Gf	--	--	--	**	--	--	--	--	*	**	
Gc	--	--	--	--	**	****	**	--	***	***	**

Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$

Table 3. Mean percent change in dimensions in and out of plastic cup (LCL and HCL refer to confidence limit bounds)

Sample	Analyst 1 (n = 50)			Analyst 2 (n = 15)			Analyst 3 (n = 15)		
	Mean (%)	95% LCL	95% HCL	Mean (%)	95% LCL	95% HCL	Mean (%)	95% LCL	95% HCL
2	8.26	4.74	11.78	--	--	--	3.41	0	8.92
3	9.47	6.10	12.84	7.73	0	19.33	--	--	--
5	3.91	1.59	6.23	--	--	--	4.50	0	12.55
6	4.32	2.81	5.83	3.87	2.64	5.11	4.94	0	11.59
7	3.85	1.48	6.22	5.50	0	17.18	2.32	0	5.71
8	6.39	3.25	9.53	--	--	--	2.17	0	6.23
9	2.73	1.11	4.34	3.76	3.29	4.24	--	--	--
Kj	3.74	2.11	5.36	3.46	2.80	4.12	--	--	--

Table 4. Dissolution

Sample	Analyst 1 (n = 50)			Analyst 2 (n = 15)			Analyst 3 (n = 15)		
	Mean (%)	95% LCL	95% HCL	Mean (%)	95% LCL	95% HCL	Mean (%)	95% LCL	95% HCL
2	102.06	100.97	103.16	--	--	--	101.60	99.35	103.86
3	101.72	100.36	103.09	102.23	101.34	103.12	--	--	--
5	102.92	101.99	103.85	--	--	--	102.69	99.86	105.51
6	103.48	102.84	104.12	104.03	100.99	107.07	103.43	98.32	108.54
7	101.50	101.20	101.80	101.22	100.00	102.44	--	--	--
8	91.88	79.51	104.24	--	--	--	97.49	84.16	110.82
9	96.99	94.03	99.95	97.79	93.24	102.35	--	--	--
Kj	102.60	101.73	103.47	103.67	101.30	106.04	102.17	101.53	102.81

Table 5. Compression test results used to measure consistency

Sample	Analyst 1 (n = 50)			Analyst 2 (n = 15)			Analyst 3 (n = 15)		
	Mean (N)	95% LCL	95% HCL	Mean (N)	95% LCL	95% HCL	Mean (N)	95% LCL	95% HCL
2	9.74	2.98	16.50	--	--	--	12.01	4.50	19.52
3	9.86	4.81	14.90	8.85	8.67	9.04	--	--	--
5	15.52	12.20	18.85	--	--	--	17.27	11.89	22.66
6	16.49	14.99	17.98	9.45	6.38	12.51	18.34	12.78	23.91
7	15.07	12.00	18.14	13.95	12.49	15.41	--	--	--
8	11.78	4.0	19.56	--	--	--	21.54	0	43.39
9	10.04	8.96	11.12	11.57	5.78	17.35	--	--	--
Kj	33.80	28.69	38.92	31.27	21.44	41.10	33.83	17.71	49.96

Supplement 1—Tables for Data Entry

Table 1. Candy dimensions.

Subsample	Inside Plastic Cup			Outside Plastic Cup		
	Height (mm) <i>H</i>	Maximum Diameter (mm) <i>D_{max}</i>	Minimum Diameter (mm) <i>D_{min}</i>	Height (mm) <i>H</i>	Maximum Diameter (mm) <i>D_{max}</i>	Minimum Diameter (mm) <i>D_{min}</i>
1						
2						
3						
4						
5						
6						
Mean						
Std. Dev.						

Table 2. Dissolution measurements.

Subsample	Initial Mass (g) M_{ini}	Final Mass (g) M_{fin}	Mass Change (g) M_{Δ}	Mass Percent (%) $M_{\%}$
1				
2				
3				
4				
5				
6				
Mean				
Std. Dev.				

Table 3. Break force measurements.

Subsample	Break Force (N)
1	
2	
3	
4	
5	
6	
Mean	
Std. Dev.	

Table 4. Slipperiness measurements (coefficient of friction)

Subsample	Friction detectable by machine? (Y/N)	Kinetic COF	Static COF
1			
2			
3			
4			
5			
6			
Mean			
Std. Dev.			

Supplement 2—Artificial Saliva Procedure

1. Dissolve 4.5 g NaCl, 0.3 g KCl, 0.3 g Na₂SO₄, 0.4 g NH₄Cl, 0.2 g urea, and 3 g lactic acid into 1 L of water. Adjust ingredients proportionally to make larger quantities. All chemical weights listed are assuming an anhydrous state. Use 2M NaOH solution to adjust pH to 5.
2. Heat solution to 37 °C.

Supplement 3—Raw Data

Table 1. Candy Dimensions (mm)

Analyst	Sample	In cup			Without Cup		
		Height	Width _{max}	Width _{min}	Height	Width _{max}	Width _{min}
1	A	29.11	47.68	36.55	31.91	47.48	35.91
1	A	29.05	47.22	36.01	32.62	49.8	36.33
1	A	28.79	47.39	36.13	31.2	49.2	39.24
1	A	28.77	47.3	35.42	29.27	48.79	35.72
1	A	28.72	47.2	34.48	25.83	50.43	35.22
2	A	29.25	56.59	37.39	27.91	44.19	33.9
2	A	29.69	56.26	36.85	28.08	48.06	35.78
2	A	29.45	56.03	36.26	30.17	47.61	36.32
1	B	28.75	47.36	34.29	30.13	46.92	35.28
1	B	29.4	47.06	36.49	34.63	50.18	38.3
1	B	28.89	47.43	36.43	32.83	49.32	37.27
1	B	28.74	47.31	35.38	28.77	52.94	35.87
1	B	28.87	47.25	36.28	24.45	49.89	34.79
2	B	29.05	55.87	37.67	29.32	46.88	38.22
2	B	29.35	56.24	36.75	28.8	45.56	36.5
2	B	29.92	56.11	36.85	31.76	47.35	37.83
1	C	28.84	46.98	36.03	33.31	49.31	36.41
1	C	30.13	47.25	36.26	33.92	47.67	35.36
1	C	29.85	47.2	35.21	35.26	49.39	36.55
1	C	28.6	47.24	35.28	29.27	49.67	35.32
1	C	28.94	47.5	35.73	28.69	51.08	37.94
2	C	29.05	55.87	37.67	29.32	46.88	38.22
2	C	29.35	56.24	36.75	28.8	45.56	36.5
2	C	29.92	56.11	36.85	31.76	47.35	37.83
3	C	29.8	47.2	37.8	29.8	40.0	45.6
3	C	29.5	47.1	37.3	28.2	45.4	39.3
3	C	29.4	47.2	38.5	30.3	43.0	39.8
1	D	28.89	19.45	29.89	30.22	21.95	31.16
1	D	28.92	20.02	29.68	29.93	20.94	30.11
1	D	28.69	19.33	29.6	29.83	21.9	30.29
1	D	28.51	18.78	28.93	28.81	19.6	29.5
1	D	28.85	19.6	29.93	27.64	21.44	30.38
1	E	38.8	48.55	27.21	39.41	48.84	26.59
1	E	38.96	47.76	26.74	40.1	48.33	26.36
1	E	38.97	48.25	27.07	39.34	47.85	26.04
1	E	38.71	48.07	25.68	33.8	47.94	23.81

1	E	38.23	48.07	26.64	34.65	47.31	23.12
2	E	38.91	57.25	26.41	37.94	46.38	23.67
2	E	38.83	56.48	25.05	38.21	44.59	24.33
2	E	38.58	56.99	26.98	34.36	45.4	23.29
1	F	37.95	47.57	27.33	39.97	48.44	26.03
1	F	38.73	48.2	27.03	41.51	47.98	25.26
1	F	37.89	48.3	27.04	40.43	50.0	24.93
1	F	38.33	48.0	25.8	37.98	49.93	24.77
1	F	38.01	47.82	25.67	33.91	48.42	24.61
2	F	38.54	56.9	26.92	39.1	46.31	23.84
2	F	37.99	56.79	26.97	37.13	45.95	25.29
2	F	38.88	56.38	26.25	33.85	44.01	24.14
3	F	38.6	47.6	26.2	37.4	43.8	25.8
3	F	39	48.1	26.7	37.4	43.6	24.8
3	F	38.4	48.1	26.6	35.3	46.2	24.8
1	G	36.65	36.47	28.56	36.29	38.21	28.38
1	G	36.58	36.85	29.04	37.27	37.6	28.09
1	G	36.52	37.06	29.65	36.2	36.26	28.04
1	G	36.08	35.99	28.55	33.7	37.73	28.74
1	G	35.9	36.2	28.9	36.98	37.52	28.89
2	G	36.65	47.8	29.13	38.09	37.02	27.2
2	G	36.05	46.14	28.66	35.64	35.26	27.95
2	G	36.53	45.58	28.12	36.05	35.09	26.15
3	G	36.2	35.8	28.9	36.2	36.3	28.9
3	G	36.5	36.3	28.6	35.5	34.5	28.7
3	G	36.9	35.8	28.8	35.4	35.8	35.4
1	H	26.96	47.18	34.24	23.61	50.15	34.36
1	H	27.43	47.32	33.34	25.92	54.22	34.84
1	H	27.42	47.24	34.01	26.62	49.78	33.05
1	H	26.76	47.4	33.96	24.5	49.55	33.28
1	H	26.87	47.42	33.07	27.55	51.19	33.81
2	H	28.39	56.19	36.4	29.04	46.69	36.19
2	H	29	55.96	35.37	28.38	46.16	34.23
2	H	27.22	55.81	35.26	28.97	45.6	35.23
1	I	44.98	30.33	14.43	45.35	29.07	13.19
1	I	45.27	30.77	14.38	43.91	29.68	12.67
1	I	44.32	30.32	14.19	43.25	28.88	13.82
1	I	44.81	30.62	14.13	46.68	28.36	13.87
1	I	45.15	30.83	14.19	46.02	29.74	13.39
3	I	45.4	30.2	17.3	44.8	27.2	15.9
3	I	46.4	30.1	17.2	46.7	28.2	15.3
3	I	46.0	30.1	17.0	44.0	27.5	16.0

1	Konjac	33.97	35.2	24.24	33.49	33.73	21.79
1	Konjac	33.68	35.21	23.18	32.2	32.6	22.18
1	Konjac	33.57	35.46	23.72	34.57	32.68	21.28
1	Konjac	33.64	35.3	23.14	34	33.03	22.99
1	Konjac	33.43	36.02	23.7	34.94	33.77	21.5
3	Konjac	34.3	35.3	23.7	32.1	34.8	21.8
3	Konjac	33.5	35.6	23.7	31.8	33.4	22.3
3	Konjac	33.6	35.5	23.5	32.4	34.4	20.7
1	Finger Gelatin	26.96	47.33	35.9	26.73	43.37	32.51
1	Finger Gelatin	27.39	47.2	35.38	25.42	43.84	31.9
1	Finger Gelatin	27.3	47.02	35.16	26.41	43.34	30.72
1	Finger Gelatin	27.1	47.2	35.39	24.66	45.74	31.94
1	Finger Gelatin	28.61	47.44	35.49	28.21	45.1	33.46
1	Premade Gelatin	45.03	59.73	50.56	39.36	58.48	46.95
1	Premade Gelatin	41.49	59.23	50.64	38.63	57.54	47.58
1	Premade Gelatin	44.49	58.68	50.41	39.15	58.3	48.71
1	Premade Gelatin	41.79	57.87	50.62	39.25	64.13	53.76
1	Premade Gelatin	41.74	57.92	50.89	43.66	60.07	50.87

Table 2. Dissolution

Analyst	Sample	Mass _{initial} (g)	Mass _{final} (g)
1	A	32.04	32.66
1	A	32.72	32.87
1	A	31.62	32.18
1	A	32.04	32.11
1	A	31.95	32.21
1	B	30.83	31.67
1	B	32.42	33.09
1	B	32.42	33.05
1	B	31.23	32.14
1	B	29.83	30.03
2	B	32.16	32.81
2	B	32.1	32.28
2	B	32.3	33.02
1	C	29.58	30.07
1	C	31.18	31.56
1	C	31.95	32.04
1	C	32.86	33.91
1	C	32.76	33.51
2	C	30.33	31.03
2	C	32.61	33.44
2	C	31.48	32.06
1	D	12.89	13.01
1	D	13.07	13.23
1	D	13.13	13.17
1	D	13.09	13.37
1	D	13.36	13.63
1	E	31.13	31.66
1	E	33.56	34.71
1	E	34.55	35.63
1	E	33.12	34.03
1	E	32.94	34.12
2	E	31.83	32.41
2	E	32.19	33.47
2	E	33.15	33.9
1	F	33.34	34.3
1	F	33.85	35.05
1	F	33.07	34.07
1	F	33.31	34.64
1	F	33.86	35.2

2	F	31.86	32.2
2	F	33.4	35.0
2	F	33.1	34.57
3	F	32.56	33.42
3	F	33.15	34.79
3	F	33.51	35.02
1	G	35.76	36.25
1	G	36.29	36.71
1	G	36.59	37.16
1	G	35.27	35.86
1	G	35.91	36.54
3	G	35.75	36.21
3	G	34.54	35.12
3	G	35.64	35.89
1	H	30.87	28.2
1	H	29.87	29.18
1	H	31.91	30.91
1	H	28.62	28.24
1	H	28.69	21.46
2	H	28.55	26.09
2	H	29.5	29.93
2	H	29.82	29.71
1	I	17.42	17.23
1	I	17.92	17.47
1	I	17.87	16.92
1	I	17.31	17.23
1	I	17.13	16.16
3	I	17.03	16.3
3	I	17.08	16.94
3	I	17.17	16.91
1	Konjac	26.1	26.83
1	Konjac	25.33	26.24
1	Konjac	26.38	27.01
1	Konjac	26.46	27.14
1	Konjac	26.1	26.53
2	Konjac	25.64	26.15
2	Konjac	25.74	26.27
2	Konjac	25.14	25.76
3	Konjac	24.9	25.54
3	Konjac	25.37	26.45
3	Konjac	25.58	26.65
1	Finger Gelatin	29.74	0

1	Finger Gelatin	32.15	0
1	Finger Gelatin	26.5	0
1	Finger Gelatin	30.1	0
1	Finger Gelatin	30.66	0
1	Premade Gelatin	93.82	0
1	Premade Gelatin	95.38	0
1	Premade Gelatin	93.02	0
1	Premade Gelatin	92.68	0
1	Premade Gelatin	94.72	0

Table 3. Compressibility

Analyst	Sample	Force _{break} (N)
1	A	7.74
1	A	18.15
1	A	11.08
1	A	10.90
1	A	14.15
1	B	7.83
1	B	10.45
1	B	3.74
1	B	18.46
1	B	8.23
2	B	15.44
2	B	10.85
2	B	9.74
1	C	11.70
1	C	14.95
1	C	6.23
1	C	5.20
1	C	11.21
3	C	8.94
3	C	8.81
3	C	8.81
1	D	4.72
1	D	5.47
1	D	5.16
1	D	3.54
1	D	4.07
1	E	14.32
1	E	16.46
1	E	17.53
1	E	17.88
1	E	11.43
2	E	16.99
2	E	19.57
2	E	15.26
1	F	16.10
1	F	18.02
1	F	17.44
1	F	15.12

1	F	15.84
2	F	15.97
2	F	20.42
2	F	18.64
3	F	10.59
3	F	8.14
3	F	9.61
1	G	16.99
1	G	17.04
1	G	11.03
1	G	15.66
1	G	14.63
3	G	13.57
3	G	13.66
3	G	14.63
1	H	14.63
1	H	20.82
1	H	4.80
1	H	7.52
1	H	11.12
2	H	19.88
2	H	31.05
2	H	13.70
1	I	10.19
1	I	11.12
1	I	10.28
1	I	8.72
1	I	9.88
3	I	9.52
3	I	11.08
3	I	14.10
1	Konjac	35.67
1	Konjac	30.60
1	Konjac	38.43
1	Konjac	35.85
1	Konjac	28.47
2	Konjac	31.40
2	Konjac	28.91
2	Konjac	41.19
3	Konjac	34.25
3	Konjac	32.78
3	Konjac	26.78

1	Finger Gelatin	15.97
1	Finger Gelatin	18.64
1	Finger Gelatin	14.90
1	Finger Gelatin	14.32
1	Finger Gelatin	19.53
1	Premade Gelatin	4.04
1	Premade Gelatin	3.80
1	Premade Gelatin	4.54
1	Premade Gelatin	3.91
1	Premade Gelatin	3.69

Table 4. Friction

Sample	Mass (g)	AvgF (N)	Stat COF	Kin COF
Finger Gelatin	27.22	0.0942	0.185	0.353
Finger Gelatin	27.43	0.115	0.186	0.426
Finger Gelatin	28.14	0.139	0.434	0.502
Finger Gelatin	29.57	0.116	0.326	0.401
Finger Gelatin	28.06	0.121	0.199	0.441

Supplement 4—R Code

Compression Data

```
Group <- c(1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7, 8, 8, 8, 8, 8, 9, 9, 9, 9, 9, 10, 10, 10, 10, 10, 11, 11, 11, 11, 11, 12, 12, 12, 12, 12)
```

```
Force <- c(7.74, 18.15, 11.08, 10.9, 14.15, 7.83, 10.45, 3.74, 18.46, 8.23, 11.7, 14.95, 6.23, 5.2, 11.21, 4.72, 5.47, 5.16, 3.54, 4.07, 14.32, 16.46, 17.53, 17.88, 11.43, 16.01, 18.02, 17.44, 15.12, 15.84, 16.99, 17.04, 11.03, 15.66, 14.63, 14.63, 20.82, 4.8, 7.52, 11.12, 10.19, 11.12, 10.28, 8.72, 9.88, 35.67, 30.6, 38.43, 35.85, 28.47, 15.97, 18.64, 14.9, 14.32, 19.52, 4.04, 3.8, 4.54, 3.91, 3.69)
```

```
Av.F <- c(12.40, 9.74, 9.86, 4.59, 15.52, 16.5, 15.07, 11.78, 10.04, 33.81, 16.67, 4.0)
```

```
Dat <- data.frame(Group, Force)
```

```
plot(jitter(Group, 1.2), Force, xlab="Candy", ylab="Break Force (N)", cex=1.2)
```

```
library(Hmisc)
```

```
minor.tick(nx = 2, ny = 2, tick.ratio = 1)
```

```
points(Av, col="red", pch="-", cex=2) #use for means (easy way)
```

```
#Welch's ANOVA
```

```
oneway.test(Force ~ Group, var.equal = FALSE)
```

```
library(rstatix)
```

```
#Games-Howell Post Hoc Test
```

```
gtest <- games_howell_test(Dat, Force ~ Group, conf.level = 0.95, detailed = FALSE)
```

```
print.data.frame(gtest)
```

```
#Compression
```

```
Analyst B
```

```
ball <- c(7.74, 18.15, 11.08, 10.9, 14.15)
```

```
t.test(ball)
```

```
pan <- c(7.83, 10.45, 3.74, 18.46, 8.23)
```

```
t.test(pan)
```

```
car <- c(11.7, 14.95, 6.23, 5.2, 11.21)
```

```
t.test(car)
```

```
jel <- c(4.72, 5.47, 5.16, 3.54, 4.07)
```

```
t.test(jel)
```

```
coc <- c(14.32, 16.46, 17.53, 17.88, 11.43)
```

```
t.test(coc)
```

```
boy <- c(16.01, 18.02, 17.44, 15.12, 15.84)
```

```
t.test(boy)
```

```
pas <- c(16.99, 17.04, 11.03, 15.66, 14.63)
```

```
t.test(pas)
```

```
man <- c(14.63, 20.82, 4.8, 7.52, 11.12)
```

```
t.test(man)
```

```
aia <- c(10.19, 11.12, 10.28, 8.72, 9.88)
```

```
t.test(aia)
```

```
bir <- c(35.67, 30.6, 38.43, 35.85, 28.47)
```

```
t.test(bir)
```

```
#Analyst A
```

```
car <- c(8.94, 8.81, 8.81)
```

```
t.test(car)
```

```
boy <- c(10.59, 8.14, 9.61)
```

```
t.test(boy)
```

```
pas <- c(13.57, 13.66, 14.63)
```

```
t.test(pas)
```

```
aia <- c(9.52, 11.08, 14.10)
```

```
t.test(aia)
```

```
bir <- c(34.25, 32.78, 26.78)
```

```
t.test(bir)
```

```
#Analyst C
```

```
pan <- c(15.44, 10.85, 9.74)
```

```
t.test(pan)
```

```
coc <- c(16.99, 19.57, 15.26)
```

```
t.test(coc)
```

```
boy <- c(15.97, 20.42, 18.64)
```

```
t.test(boy)
```

```
man <- c(19.88, 31.05, 13.70)
```

```
t.test(man)
```

```
bir <- c(31.40, 28.91, 41.19)
```

```
t.test(bir)
```

Dimensional Data

```
Ht <- c(9.62, 12.29, 8.37, 1.74, 10.06, 4.80, 17.79, 13.64, 0.10, 15.31, 15.50, 12.58, 18.12, 2.34, 0.86,
4.60, 3.49, 3.97, 1.05, 4.19, 1.57, 2.93, 0.95, 12.68, 9.36, 5.32, 7.18, 6.70, 0.91, 10.79, 0.98, 1.89, 0.88,
6.60, 3.01, 12.43, 5.50, 2.92, 8.45, 2.53, 0.82, 3.00, 2.41, 4.17, 1.93, 1.41, 4.39, 2.98, 1.07, 4.52, 0.85,
7.19, 3.26, 9.00, 1.40, 12.59, 6.89, 12.00, 6.08, 4.60)
```

```
Mx <- c(0.42, 5.46, 3.82, 3.15, 6.84, 0.93, 6.63, 3.98, 11.90, 5.59, 4.96, 0.89, 4.64, 5.14, 7.54, 12.85, 4.60,
13.30, 4.37, 9.39, 0.60, 1.19, 0.83, 0.27, 1.58, 1.83, 0.46, 3.52, 4.02, 1.25, 4.77, 2.04, 2.16, 4.83, 3.65,
6.30, 14.58, 5.38, 4.54, 7.95, 4.15, 3.54, 4.75, 7.38, 3.54, 4.18, 7.41, 7.84, 6.43, 6.25, 8.37, 7.12, 7.83,
3.09, 4.93, 2.09, 2.85, 0.65, 10.82, 3.71)
```

```
Mn <- c(1.75, 0.89, 8.61, 0.85, 2.15, 2.89, 4.96, 2.31, 1.38, 4.11, 1.05, 2.48, 3.81, 0.11, 6.19, 4.25, 1.45,
2.33, 1.97, 1.50, 2.28, 1.42, 3.80, 7.28, 13.21, 4.76, 6.55, 7.80, 3.99, 4.13, 0.63, 3.27, 5.43, 0.67, 0.03,
0.35, 4.50, 2.82, 2.00, 2.24, 8.59, 11.89, 2.61, 1.84, 5.64, 10.11, 4.31, 10.29, 0.65, 9.28, 9.44, 9.84, 12.63,
9.75, 5.72, 7.14, 6.04, 3.37, 6.20, 0.04)
```

```
Group <- c(1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7, 8, 8, 8,
8, 8, 9, 9, 9, 9, 9, 10, 10, 10, 10, 10, 10, 11, 11, 11, 11, 11, 12, 12, 12, 12, 12)
```

```
points(Av, col="red", pch="-", cex=2) #use for means (easy way)
```

```
Ht <- c(9.62, 12.29, 8.37, 1.74, 10.06, 4.80, 17.79, 13.64, 0.10, 15.31, 15.50, 12.58, 18.12, 2.34, 0.86,
4.60, 3.49, 3.97, 1.05, 4.19, 1.57, 2.93, 0.95, 12.68, 9.36, 5.32, 7.18, 6.70, 0.91, 10.79, 0.98, 1.89, 0.88,
```

```
6.60, 3.01, 12.43, 5.50, 2.92, 8.45, 2.53, 0.82, 3.00, 2.41, 4.17, 1.93, 1.41, 4.39, 2.98, 1.07, 4.52, 0.85,
7.19, 3.26, 9.00, 1.40, 12.59, 6.89, 12.00, 6.08, 4.60)
```

```
Av.Ht <- c(8.42, 10.33, 9.88, 3.46, 5.5, 6.18, 2.67, 6.36, 2.47, 2.87, 4.34, 8.43)
```

```
Group <- c(1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7, 8, 8, 8,
8, 8, 9, 9, 9, 9, 10, 10, 10, 10, 10, 11, 11, 11, 11, 11, 12, 12, 12, 12, 12)
```

```
data.frame(Group, Ht)
```

```
plot(jitter(Group, 1.2), Ht, xlab="Candy", ylab="Percent Change in Height", cex=2)
```

```
library(Hmisc)
```

```
minor.tick(nx = 2, ny = 2, tick.ratio = 1)
```

```
points(Av.Ht, col="red", pch="-", cex=2)
```

```
Mx <- c(0.42, 5.46, 3.82, 3.15, 6.84, 0.93, 6.63, 3.98, 11.90, 5.59, 4.96, 0.89, 4.64, 5.14, 7.54, 12.85, 4.60,
13.30, 4.37, 9.39, 0.60, 1.19, 0.83, 0.27, 1.58, 1.83, 0.46, 3.52, 4.02, 1.25, 4.77, 2.04, 2.16, 4.83, 3.65,
6.30, 14.58, 5.38, 4.54, 7.95, 4.15, 3.54, 4.75, 7.38, 3.54, 4.18, 7.41, 7.84, 6.43, 6.25, 8.37, 7.12, 7.83,
3.09, 4.93, 2.09, 2.85, 0.65, 10.82, 3.71)
```

```
Av.Mx <- c(3.94, 5.81, 4.63, 8.9, 0.9, 2.22, 3.49, 7.75, 4.67, 6.42, 6.27, 4.02)
```

```
Group <- c(1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7, 8, 8, 8,
8, 8, 9, 9, 9, 9, 10, 10, 10, 10, 10, 11, 11, 11, 11, 11, 12, 12, 12, 12, 12)
```

```
data.frame(Group, Mx)
```

```
plot(jitter(Group, 1.2), Ht, xlab="Candy", ylab="Percent Change in Maximum Diameter", cex=2)
```

```
library(Hmisc)
```

```
minor.tick(nx = 2, ny = 2, tick.ratio = 1)
```

```
points(Av.Mx, col="red", pch="—", cex=2)
```

```
Mn <- c(1.75, 0.89, 8.61, 0.85, 2.15, 2.89, 4.96, 2.31, 1.38, 4.11, 1.05, 2.48, 3.81, 0.11, 6.19, 4.25, 1.45,
2.33, 1.97, 1.50, 2.28, 1.42, 3.80, 7.28, 13.21, 4.76, 6.55, 7.80, 3.99, 4.13, 0.63, 3.27, 5.43, 0.67, 0.03,
0.35, 4.50, 2.82, 2.00, 2.24, 8.59, 11.89, 2.61, 1.84, 5.64, 10.11, 4.31, 10.29, 0.65, 9.28, 9.44, 9.84, 12.63,
9.75, 5.72, 7.14, 6.04, 3.37, 6.20, 0.04)
```

```
Av.Mn <- c(2.85, 3.13, 2.73, 2.30, 5.6, 5.45, 2.01, 2.38, 6.11, 6.93, 9.48, 4.56)
```

```
Group <- c(1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7, 8, 8, 8,
8, 8, 9, 9, 9, 9, 9, 10, 10, 10, 10, 10, 11, 11, 11, 11, 11, 12, 12, 12, 12, 12)
```

```
data.frame(Group, Mn)
```

```
plot(jitter(Group, 1.2), Ht, xlab="Candy", ylab="Percent Change in Minimum Diameter", cex=2)
```

```
library(Hmisc)
```

```
minor.tick(nx = 2, ny = 2, tick.ratio = 1)
```

```
points(Av.Mn, col="red", pch="—", cex=2)
```

```
Tot <- c(3.93, 6.21, 6.93, 1.91, 6.35, 2.87, 9.79, 6.64, 4.46, 8.33, 7.17, 5.32, 8.86, 2.53, 4.86, 7.24, 3.18,  
6.53, 2.46, 5.03, 1.48, 1.85, 1.86, 6.75, 8.05, 3.97, 4.73, 6.01, 2.98, 5.39, 2.13, 2.40, 2.82, 4.03, 2.23, 6.36,  
8.20, 3.71, 4.99, 4.24, 4.52, 6.15, 3.26, 4.46, 3.70, 5.23, 5.37, 7.04, 2.72, 6.68, 6.22, 8.05, 7.90, 7.28, 4.02,  
7.27, 5.26, 5.34, 7.70, 2.78)
```

```
Av.Tot <- c(5.07, 6.42, 5.75, 4.89, 4, 4.61, 2.72, 5.5, 4.42, 5.41, 6.69, 5.67)
```

```
Group <- c(1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7, 8, 8, 8,  
8, 8, 9, 9, 9, 9, 9, 10, 10, 10, 10, 10, 11, 11, 11, 11, 11, 12, 12, 12, 12, 12)
```

```
data.frame(Group, Tot)
```

```
plot(jitter(Group, 1.2), Tot, xlab="Candy", ylab="Percent Change in Minimum Diameter", cex=2)
```

```
library(Hmisc)
```

```
minor.tick(nx = 2, ny = 2, tick.ratio = 1)
```

```
points(Av.Tot, col="black", pch="-", cex=2)
```

```
#Welch's ANOVA
```

```
Dat <- data.frame(Group, Tot)
```

```
oneway.test(Tot ~ Group, var.equal = FALSE)
```

```
library(rstatix)

#Games-Howell Post Hoc Test
gtest <- games_howell_test(Dat, Tot ~ Group, conf.level = 0.95, detailed = FALSE)

print.data.frame(gtest)

#RESULT
  One-way analysis of means (not assuming equal variances)

data: Tot and Group
F = 2.9361, num df = 11.000, denom df = 18.769, p-value = 0.01943

#95% CI code

#Analyst A
t.test(pas)

boy2 <- c(102.6412776, 104.9472097, 104.5061176)

t.test(boy2)

car <- c(102.3079459, 102.5452315, 101.8424396)

t.test(car)
```

```
bir2 <- c(102.5702811, 104.2569965, 104.1829554)
```

```
t.test(bir2)
```

```
Aii <- c(95.71344686, 99.18032787, 98.48573093)
```

```
t.test(Aii)
```

```
#Analyst A
```

```
ball <- c(101.9350811, 100.4584352, 101.771031, 100.2184769, 100.8137715)
```

```
t.test(ball)
```

```
pan <- c(102.7246189, 102.0666255, 101.9432449, 102.9138649, 100.670466)
```

```
t.test(pan)
```

```
coc <- c(101.7025377, 103.4266985, 103.1259045, 102.7475845, 103.5822708)
```

```
t.test(coc)
```

```
pas <- c(101.3702461, 101.1573436, 101.5578027, 101.6728098, 101.754386)
```

```
t.test(pas)
```

```
boy <- c(102.8794241, 103.5450517, 103.0238887, 103.992795, 103.9574719)
```

```
t.test(boy)
```

```
man <- c(91.35082604, 97.68998996, 96.86618615, 98.67225716, 74.79958174)
```

```
t.test(man)
```

```
car <- c(101.6565247, 101.21873, 100.2816901, 103.1953743, 102.2893773)
```

```
t.test(car)
```

```
Ai <- c(98.90929966, 97.48883929, 94.68382764, 99.5378394, 94.33741973)
```

```
t.test(Ai)
```

```
jel <- c(100.9309542, 101.2241775, 100.3046458, 102.1390374, 102.0209581)
```

```
t.test(jel)
```

```
bir <- c(102.7969349, 103.592578, 102.3881729, 102.5699169, 101.6475096)
```

```
t.test(bir)
```

```
#Analyst C
```

```
Pas <- c(3.81, 1.13, 2.02)
```

```
t.test(Pas)
```

```
Coc <- c(3.58, 1.81, 8.10)
```

```
t.test(Coc)
```

```
Boy <- c(4.46, 2.53, 7.82)
```

```
t.test(Boy)
```

```
Pan <- c(3.32, 1.23, 5.67)
```

```
t.test(Pan)
```

```
Man <- c(2.20, 0.52, 3.79)
```

```
t.test(Man)
```

Dissolution Data

```
Label <- c("A", "A", "A", "A", "A", "B", "B", "B", "B", "B", "C", "C", "C", "C", "C", "D", "D", "D", "D", "D",
"E", "E", "E", "E", "E", "F", "F", "F", "F", "F", "G", "G", "G", "G", "G", "H", "H", "H", "H", "H", "H", "I", "I", "I", "I",
"I", "Konjac", "Konjac", "Konjac", "Konjac", "Konjac", "Gelatin", "Gelatin", "Gelatin", "Gelatin", "Gelatin",
"Gelatin", "Gelatin", "Gelatin", "Gelatin", "Gelatin")
```

```
Per <- c(101.94, 100.46, 101.77, 100.21, 100.81, 102.72, 102.07, 101.94, 102.91, 100.67, 101.66, 101.22,
100.28, 103.20, 102.29, 100.93, 101.22, 100.30, 102.14, 102.02, 101.70, 103.43, 103.13, 102.75, 103.58,
102.88, 103.55, 103.02, 103.99, 103.96, 101.37, 101.16, 101.56, 101.67, 101.75, 91.35, 97.69, 96.87,
98.67, 74.80, 98.91, 97.49, 94.68, 99.54, 94.34, 102.80, 103.59, 102.39, 102.57, 101.65, 0, 0, 0, 0, 0, 0, 0,
0, 0, 0)
```

```
Group <- c(1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 4, 4, 4, 4, 4, 5, 5, 5, 5, 5, 6, 6, 6, 6, 6, 7, 7, 7, 7, 7, 8, 8, 8,
8, 8, 9, 9, 9, 9, 9, 10, 10, 10, 10, 10, 10, 11, 11, 11, 11, 11, 12, 12, 12, 12, 12)
```

```
Av.Pc <- c(101.04, 102.06, 101.73, 101.32, 102.92, 103.48, 101.50, 91.88, 96.99, 102.60, 0.00, 0.00)
```

```
Diss <- data.frame(Label, Per, Group)
```

```
library(Hmisc)
```

```
plot(jitter(Group), Per)
```

```
minor.tick(nx = 2, ny = 2, tick.ratio = 1)
```

```
gap.plot(jitter(Group), Per, gap=c(10, 70), xlab="Candy", ylab="Percent Mass Change", cex = 2)
```

```
points(Av, col="black", pch="-", cex=2) #use for means (easy way)
```

```
library(plotrix)
```

```
axis.break(2, 10, breakcol="snow", style="gap")
```

```
axis.break(2, 10*(1+0.02), breakcol="black", style="slash")
```

```
axis.break(4, 10*(1+0.02), breakcol="black", style="slash")
```