Exploring the Potential Use of Teff as an Alternative Grain Crop in Virginia

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OCTOBER 7, 2022

Outline

WHY TEFF?

- **History**
  - **Origin and adaptation**
  - **About the plant/seed, and types**
  - **Establishment**
  - **Challenges**
  - **Use**
  - **Chemical Composition**

TEFF TRIALS

Objectives of study

RESULTS

Steeles Tavern

Baked products

Why Teff

- **Shifting trends in consumer preferences to healthier specialty foods**
  - **Teff (Eragrostis tef (Zucc.) has many characteristics that may make it a viable candidate to fulfill this niche.**
  - **Has a unique nutrient composition.**
  - **Unlike most cereal grains, teff has a complete set of essential amino acids and is higher in**

    Lysine, the most limiting amino acid, in all cereals, except oats and rice (Ketema, 1997).
- **Teff is high in iron and has more calcium, copper, zinc, aluminum and barium than winter wheat, barley and sorghum (Abebe, 2007; Ketema, 1997; Mengesha, 1966).**
- **Above all, teff is well known for its gluten free flour.**

Forget quinoa and kale, the next big thing is Ethiopian super-grain teff

Teff could be the next quinoa as Ethiopia boosts exports

Teff: (*Eragrostis tef (Zucc.) Trotter*)

- Originated and domesticated in Ethiopia
- Ancient grain crop
- Warm-season, annual
- Native habitat:
  - Day length: 12 hrs.
  - Rainfall: 300-500 mm (12-20 inches)per growing season
  - Temperature: 10-27°C (50-80°F)

The Plant and Seed

Plant

- Annual bunch grass
- Loose or compacted panicle flowers
- Shallow, fibrous root system

Seed

- Teff is the smallest grain in the world.
- The grains are just over 1 mm long and less than a mm wide.
- <u>1000 teff seeds have a weight of about 0.3 to 0.4 grams</u>

0.7 – 1.0 mm seed

Teff: 1.5 – 1.7 million seeds per lb

Types and Marketing

- **Three distinct types/colors classifications determine price:**
  - **<u>White, red and brown</u>**
  - **White most expensive ($30-53/220 lbs)**
  - **Red and brown ($23-30/220 lbs)**
- **High price around festive season, especially for white Teff**
- **Sold unprocessed, whole grain**
- **Households process further by taking grain to mills**

Adaptation

- The crop is adapted to divers soils marginal to the production of most other crops.
- It is adapted to environments ranging from drought stress to water logged soil conditions.
- Acid/toxic soils, vertisols (soil high in clay – swell and shrink when wet and dry)
- Maximum teff production occurs at altitudes of 1800 to 2100 m (5760-6720 ft) (B'burg 633 m (2000 ft)
- With a temperature range of 10 to 27 °C (50-80°F).
  - Average annual rainfall is about 750-1000 mm (29-39") in the central Ethiopian highland

"black cotton" soils in East Africa)

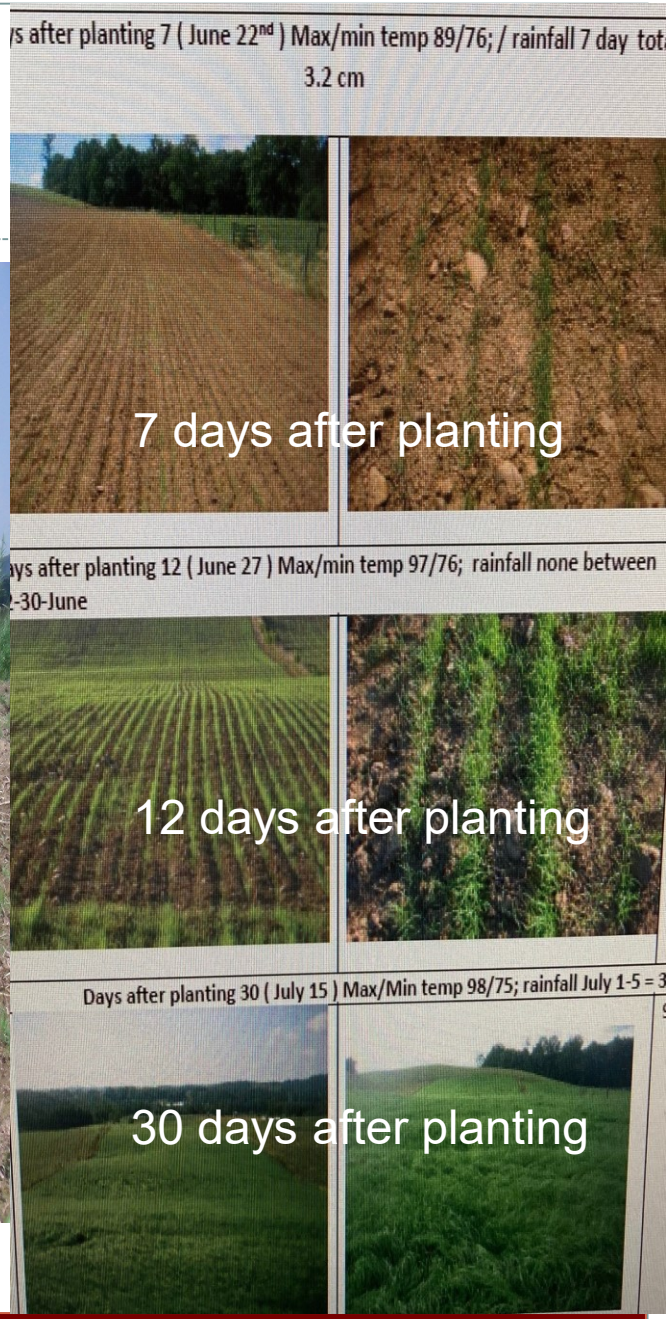
Highland and Low-land Production

- In flatland as well as highlands of Ethiopia
- The highlands are notoriously difficult to navigate.

Establishment

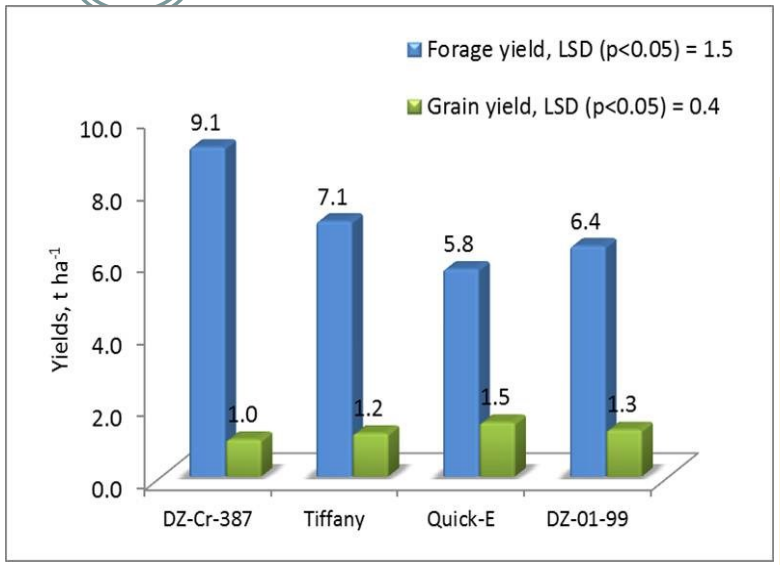
- Seeding Rate: 15 kg ha^{-1}
- Planting Depth: 0.6-1.3 cm
- Cultipacker seeder or conventional, no-till grain drill equipped with small seed box
- 60 kg ha^{-1} N fertilization
- Germinates in 3-7 days


10 days after planting



Challenge/Problem: #1 In teff

- Low Yield
- 1. Ethiopia: National average +< 1 ton/ha. Max yield 2.5 tons/ha
- 2. Holland and USA (Idaho): 1.3-2.5 tons/ha



25 lb. Grain | ጽሀፅ

$65.00

Challenge/Problem #2

- Production Practices
- Labor Intensive
  - Land preparation
  - Weed control
  - Harvesting
  - Threshing

Ethiopia

Australia

https://www.youtube.com/watch?v=6syTkQXE7P4

Harvesting and Threshing Teff in Ethiopia

- Harvested by hand when vegetative part of plant turns yellow
- Varies between 60-120 days from planting to harvest
- Oxen trample grass to separate grain from head
- Grain is cleaned by <u>wafting air over grain to blow chaff from mix using hard leather strap</u>

Uses of Teff

- Staple food in Ethiopia
  - Consists of 2/3 diet
- Injera
  - Eaten with meat sauce called wot or with faba beans, lentils, field peas, chickpeas
- Can be mixed with other baking flours to make breads, muffins, or cookies

High quality straw and forage crop for hay and grazing

Amino Acid Profile

Amino Acid	Tef	Barley	Maize	Oat	Rice	Sorghum	Wheat	Pearl Millet
Lysine	3.68	3.46	2.67	3.71	3.79	2.02	2.08	2.89
Isoleucine	4	3.58	3.68	3.78	3.81	3.92	3.68	3.09
Leucine	8.53	6.67	12.5	7.26	8.22	13.3	7.04	7.29
Valine	5.46	5.04	4.85	5.1	5.5	5.01	4.13	4.49
Phenylalanine	5.69	5.14	4.88	5	5.15	4.9	4.86	3.46
Tyrosine	3.84	3.1	3.82	3.3	3.49	2.67	2.32	1.41
Tryptophan	1.3	1.54	0.7	1.26	1.25	1.22	1.07	1.62
Threonine	4.32	3.31	3.6	3.31	3.9	3.02	2.69	2.5
Histidine	3.21	2.11	2.72	2.1	2.5	2.14	2.08	2.08
Arginine	5.15	4.72	4.19	6.29	8.26	3.07	3.54	3.48
Methionine	4.06	1.66	1.92	1.68	2.32	1.39	1.46	1.35
Cystine	2.5							3.19

Chemical Composition

Chemial Element	Brown Tef	White Tef	Spring Wheat	Winter Wheat	Winter Barley	Sorghum
K (%)	0.36	0.20	0.37	0.33	0.44	0.44
P (%)	0.44	0.46	0.51	0.4	0.48	0.52
Ca (%)	0.18	0.17	<0.1	<0.1	<0.1	<0.1
Mg (%)	0.18	0.19	0.15	0.12	0.13	0.18
Mn (ppm)	21.2	30	53	36	12	29
Fe (ppm)	196	115	78.5	40	35	66.5
B (ppm)	14	13	12	11.5	11	16.5
Cu (ppm)	53	36	20	11	14	23.5
Zn (ppm)	67	67.5	60	39.5	45	44
Al (ppm)	83	0.12	<0.1	<0.1	<0.1	<0.1%
Mo (ppm)	0.78	0.74	0.6	0.55	0.4	0.45
Co (ppm)	0.52	0.64	0.6	0.55	0.3	0.30
Na (ppm)	220	212.2	195	168.5	392	141.5
Ba (ppm)	19	23.5	7.5	6	7	<0.10

Celiac Disease

- **Teff is frequently used by Dutch Celiac Disease (CD) patients**
  - **Majority can consume teff without experiencing any clinical symptoms.**
- **CD patients using teff reported a significant reduction in symptoms (Hopman et al., 2009)**
  - **Possibly related to a reduction in gluten intake or**
  - **An increase in fiber intake.**
    - **Teff can be a valuable addition to the GFD of CD patients.**

Table I. Distribution of symptoms reported by biopsy-proven celiac patients before and after tef consumption and on a regular gluten-free diet. (Hopman 2008).

	With tef consumption ($n=1023$)		Without tef consumption ($n=522$)
Symptom (%)	Before introduction of tef in GFD	After introduction of tef in GFD	On GFD
Abdominal pain	20	$10^{\star,\#}$	23
Bloated feeling	18	$7^{\star,\#}$	18
Diarrhea	17	$8^{\star,\#}$	20
Lassitude	30	$5^{\star,\#}$	33
Constipation	14	$2^{\star,\#}$	16
Nausea	7	$3^{\star,\#}$	9
Anorexia	4	$2^{\star,\#}$	5
Depression	4	$1^{\star}$	6
Aphthous ulcers	8	$0.7^{\star,\#}$	9
Muscle weakness	8	$0.6^{\star,\#}$	8
Migraine	5	$0.4^{\star,\#}$	6
Vomiting	$2^{\S}$	$0.4^{\star}$	3
Weight loss	4	$0.4^{\star}$	6
Epilepsy	0.2	$0^{\star}$	0.8

Abbreviation: GFD = gluten-free diet.
$^{\star}p<0.05$ between symptoms after introduction of tef in a GFD and on a GFD; $^{\#}p<0.05$ between symptoms before and after introduction of tef in GFD; $^{\S}p<0.05$ between symptoms before introduction of tef in a GFD and on a GFD.

"An immune disorder whereby the small intestine is injured when exposed to gluten, a protein found in wheat and related grains..". The most accurate test for celiac disease is a biopsy of the small bowel." (WebMd 2009)

Ethiopia Goes to Top Court to Get Teff Patent from Dutch Firm

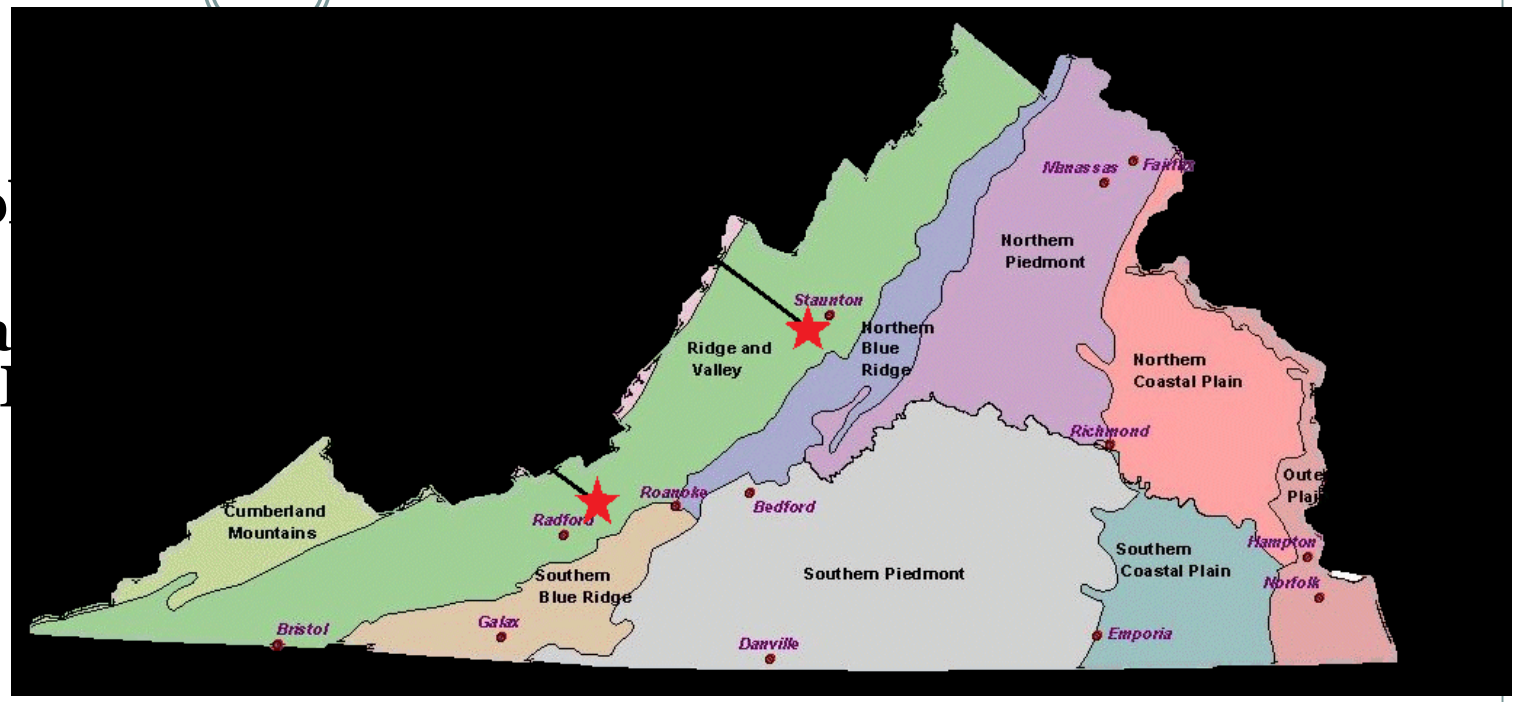
A 2005 agreement between Ethiopia and the Dutch firm gave it access to 12 teff varieties to develop new teff-based products for the European market. The company was to share the proceeds with Ethiopia, instead Health and Performance Food International patented the teff. The case went before the International Court of Arbitration.

Latif Dahir February 7, 2019

A legal tussle over who owns teff, Ethiopia's staple grain, has been quietly settled. A three-judge court in the Netherlands ruled a European patent for the products made of teff lacked "inventiveness," ending a years-long controversy over who owned the ancient grain. The controversial patent, which was originally filed in 2003, listed Dutchman Jans Roosjen as the inventor of the teff flour that's used to make injera flatbread and other traditional Ethiopian food.

Assessing Adaptations and Grain Yield Potential of Teff in Virginia

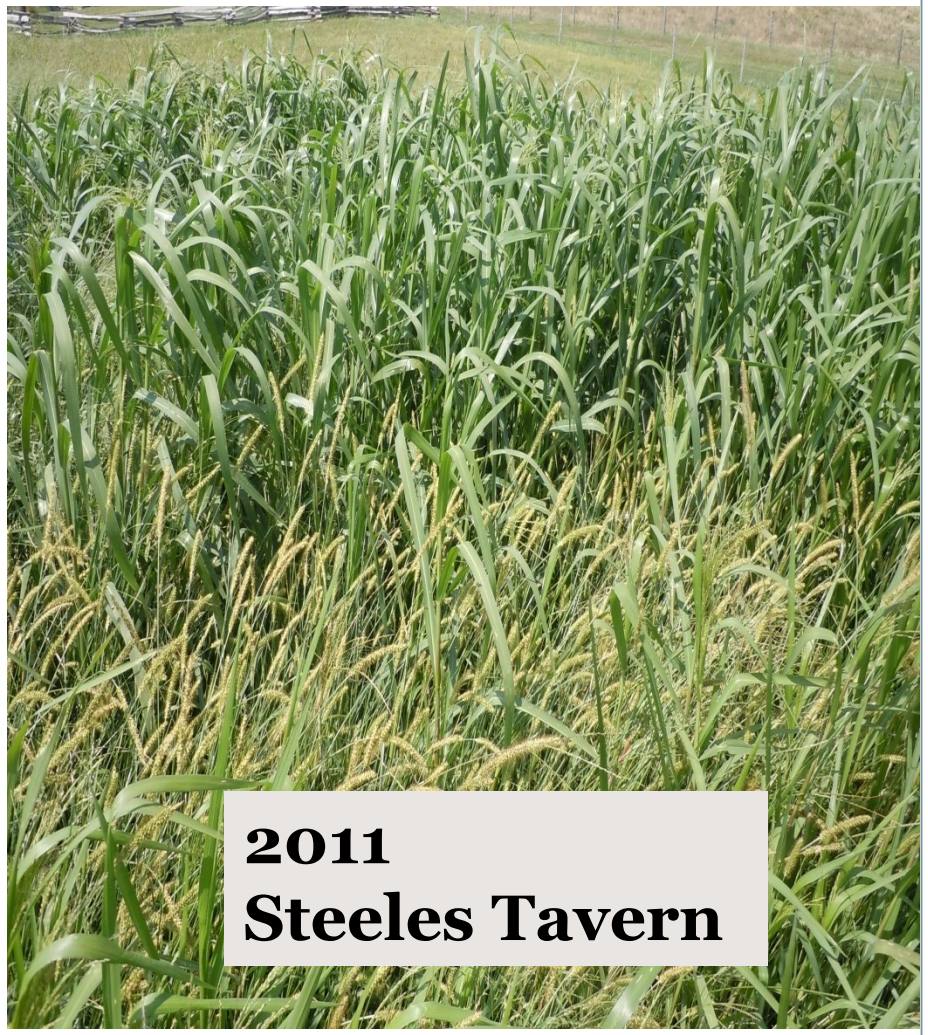
- 2010, 2011 small plot experiments
- Conducted in 2 physiograp regions in Virginia
  - Blacksburg (Kentland Fa and Steeles Tavern (SVA
- 2 types
  - Brown and white
- 2 planting dates
  - June and July
- 4 replications



Teff Grain/Field trials in Virginia

- **Two Objectives:**
  - **To assess adaptations of teff and grain yield potential at two physiographic regions in Virginia**
  - **To determine the suitability of teff flour in baked products**

Mixed Results…



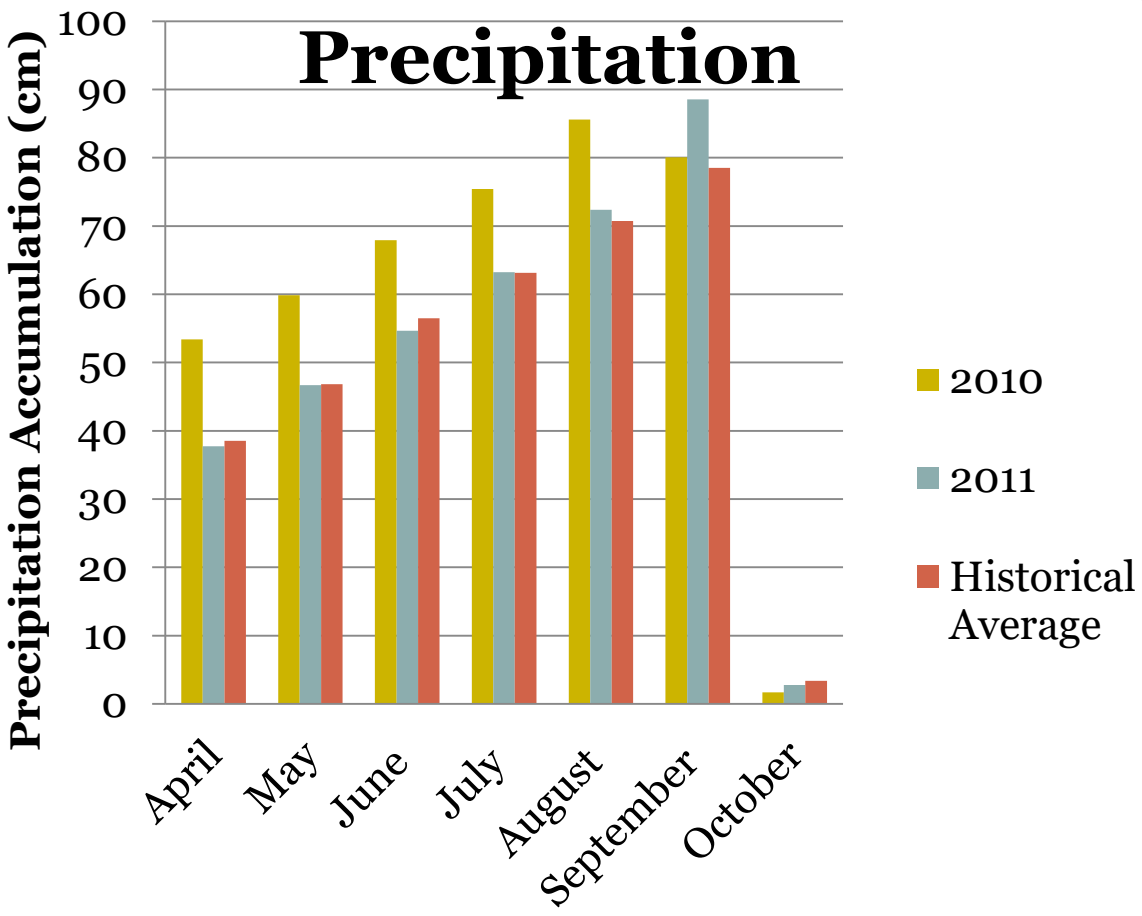
Steeles Tavern

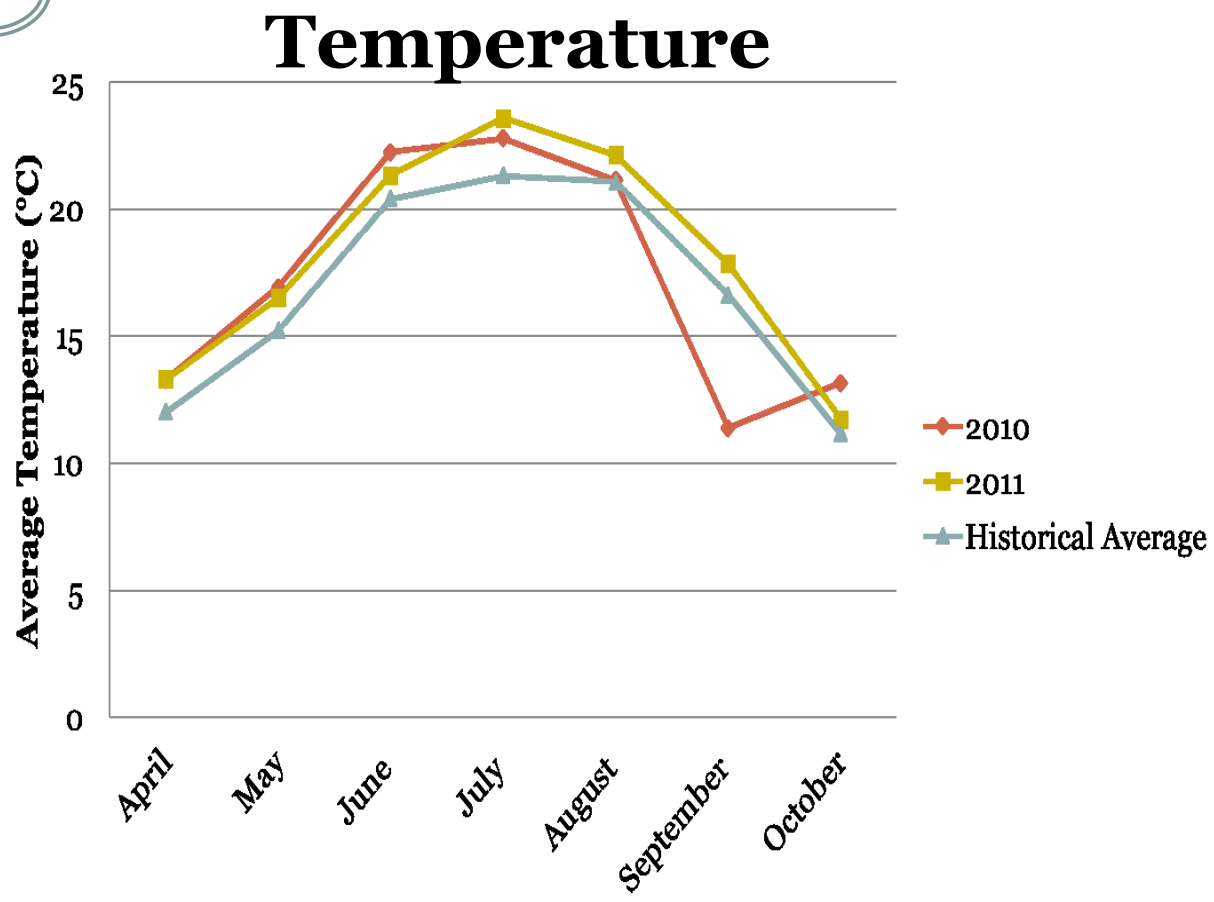
Planting

- **Seeding rate: 6.7 kg PLS ha^{-1}**
- **56 kg ha^{-1} N**

Harvesting

- **October 19, 2010**
- **40 in self-propelled sickle mower**
- **Samples placed in dryer at 74°C**

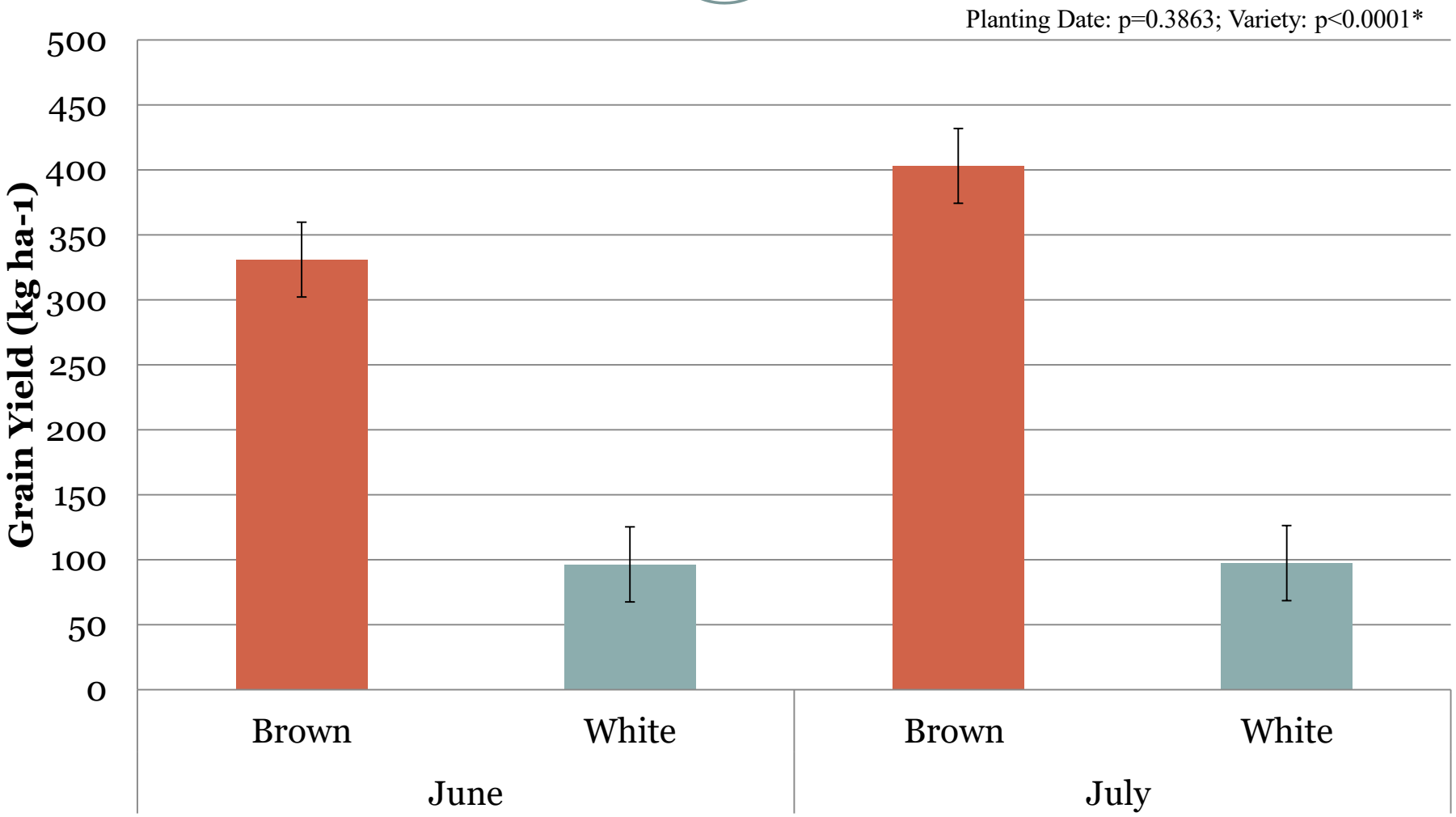

Precipitation
Precipitation Accumulation (cm)
100
90
80
70
60
50
40
30
20
10
0
April
May
June
July
August
September
October
2010
2011
Historical Average


Temperature
Average Temperature (°C)
25
20
15
10
5
0
April
May
June
July
August
September
October
2010
2011
Historical Average

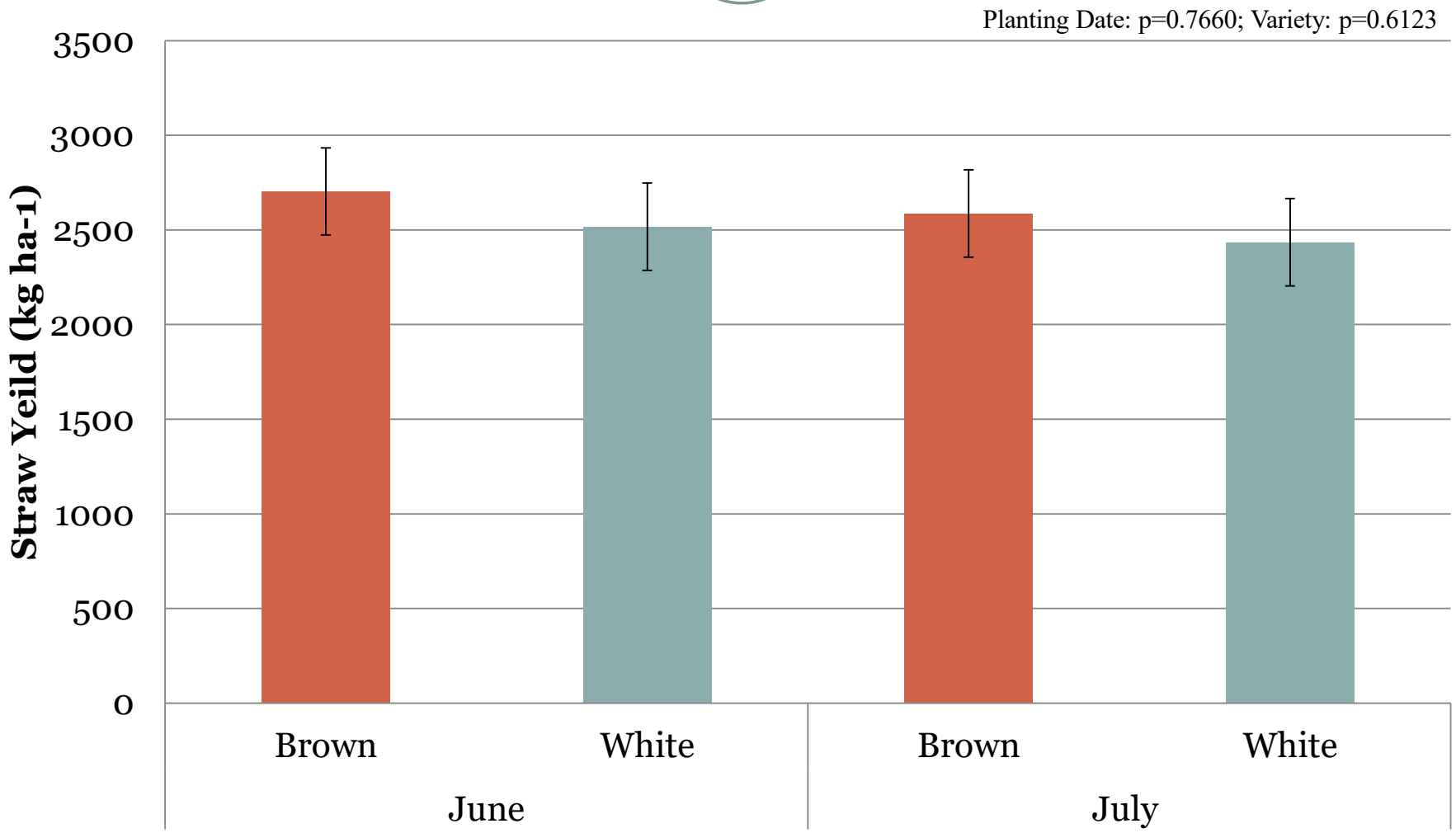
2010 Steeles Tavern

- Threshing
  - Mat and rubber grout
  - Small-grain thresher
- Grain Cleaning
  - Soil sieves and sorting pans
  - Clipper Office Tester
    - Air-screen cleaner
    - Small-lot cleaning

Teff Grain Yield



Teff Straw Yield



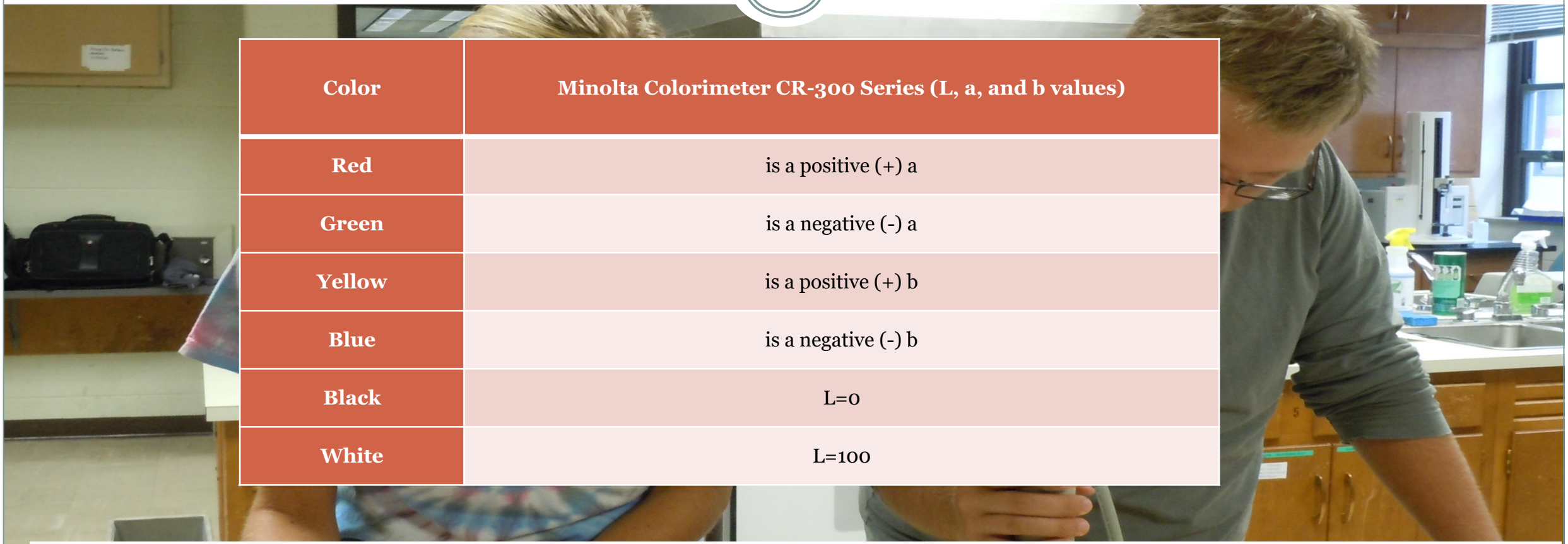
Baking Characteristics

- 4 Products:
  - Cakes, Cookies, Breads, Biscuits
- Treatments
  - 3 replications per treatment
- Used size, shape, color, volume, and texture to evaluate the quality of the baked products
- Nutrient Analysis

Treatment	Treatment Composition	
	Teff Flour (%)	Wheat Flour (%)
1	0	100
2	10	90
3	20	80
4	30	70
5	40	60
6	100	0

Human Foods, Nutrition and Exercise Department at Virginia Tech.

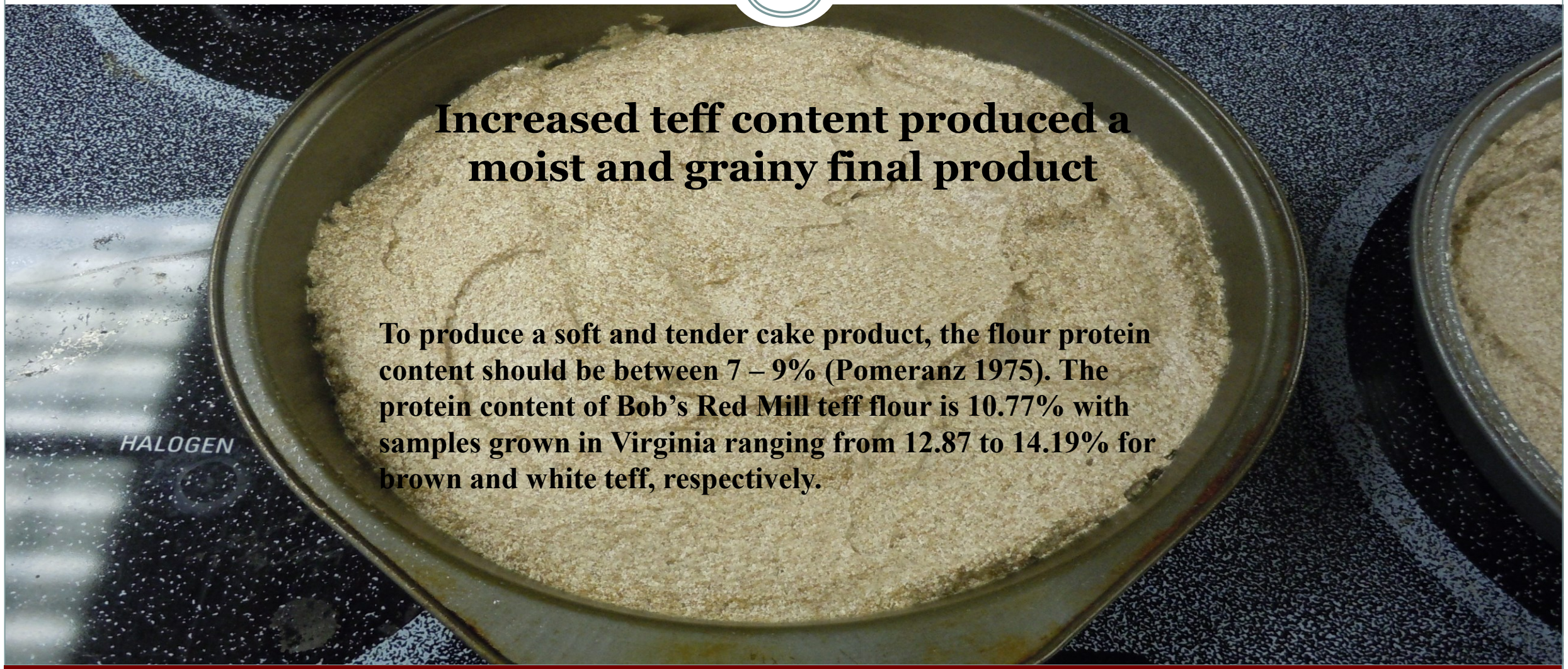
Hunter L, a and b-values



Color	Minolta Colorimeter CR-300 Series (L, a, and b values)
Red	is a positive (+) a
Green	is a negative (-) a
Yellow	is a positive (+) b
Blue	is a negative (-) b
Black	L=0
White	L=100

"Represent a color space created for measuring the color of an object where L* measures the lightness of a color and a* and b* are equal to chromaticity, indicating the direction of the color coordinate." (Cachaper 2005)

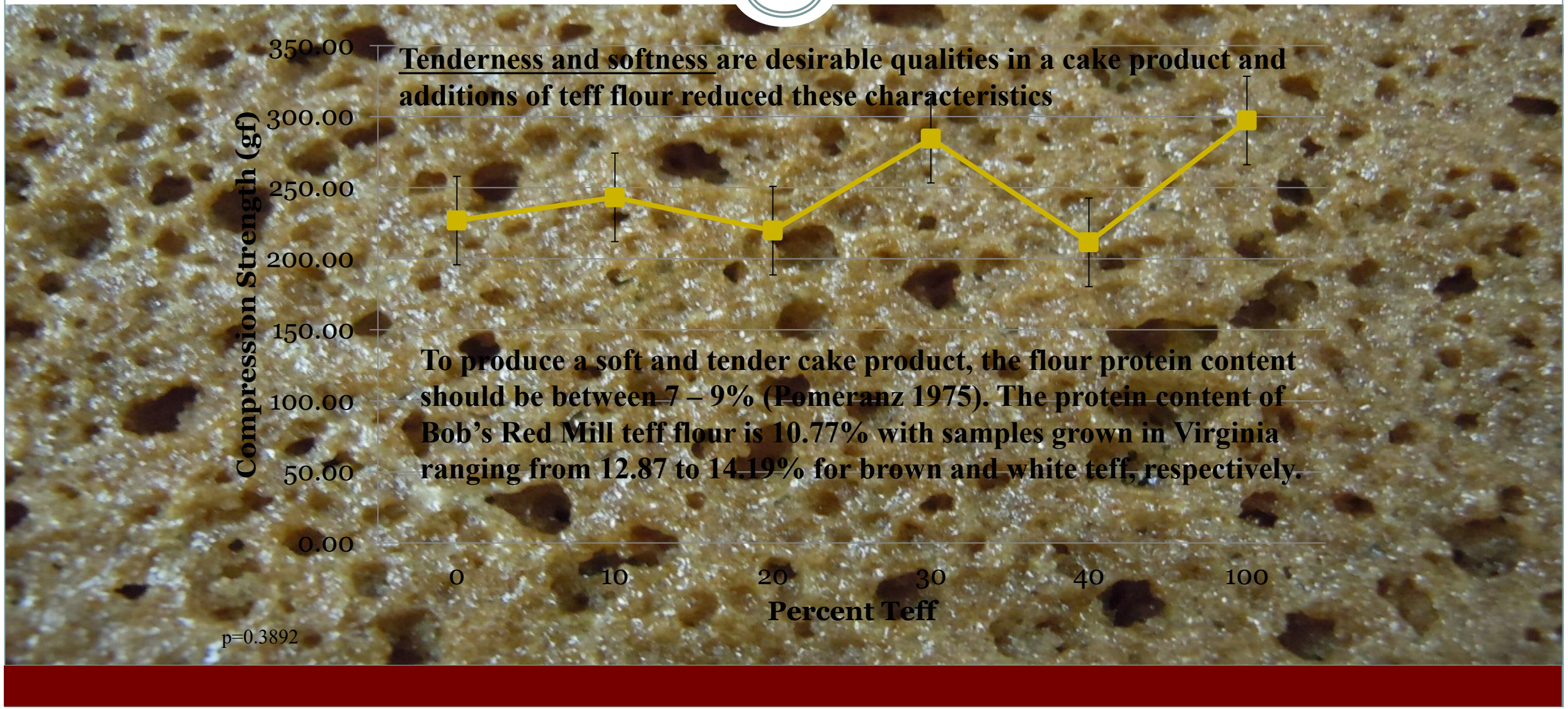
Cake Texture



Increased teff content produced a moist and grainy final product

To produce a soft and tender cake product, the flour protein content should be between 7 – 9% (Pomeranz 1975). The protein content of Bob's Red Mill teff flour is 10.77% with samples grown in Virginia ranging from 12.87 to 14.19% for brown and white teff, respectively.

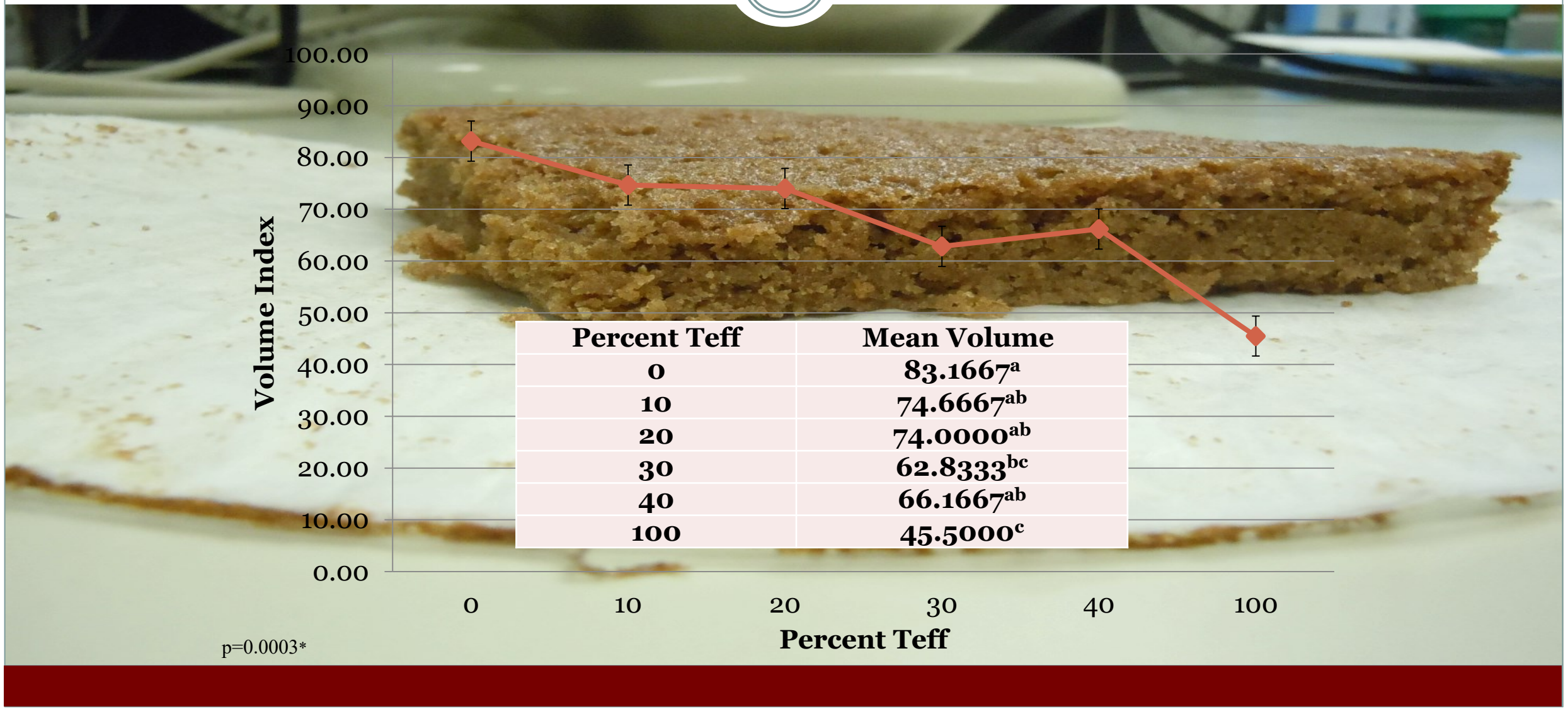
Cake Texture



Cake Volume

The volume of the cake samples was most affected by protein quality.

Cake Volume

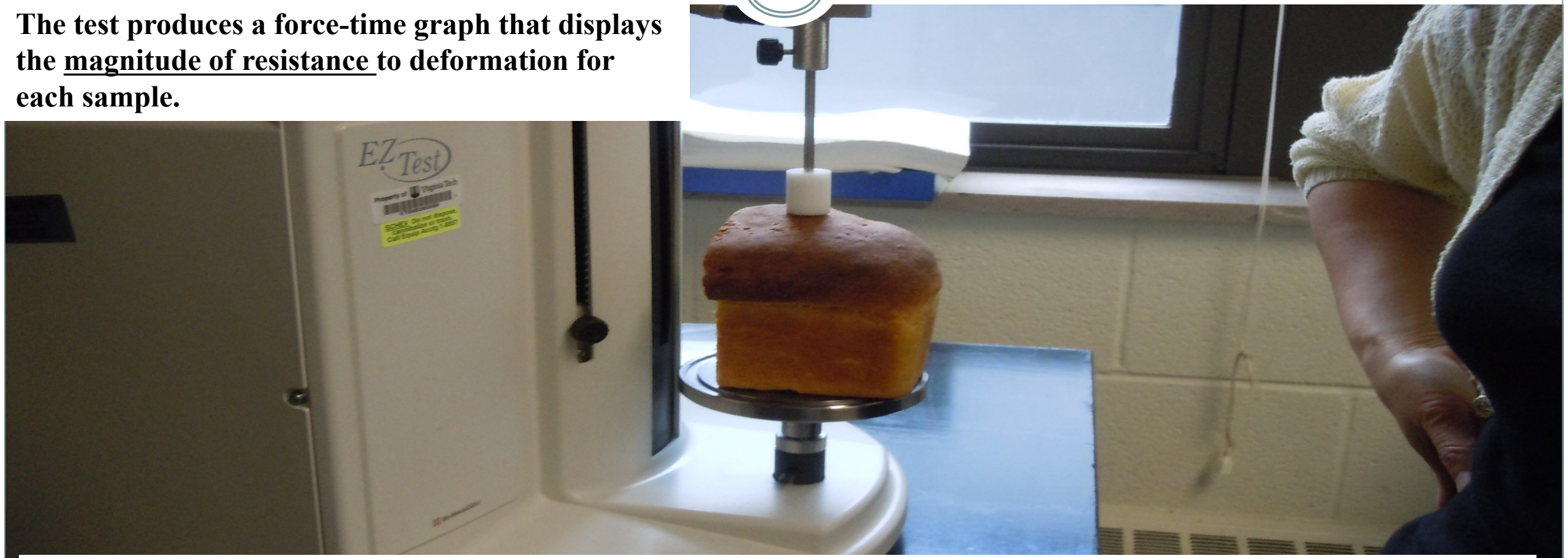


Percent Teff	Mean Volume
0	83.1667[a]
10	74.6667[ab]
20	74.0000[ab]
30	62.8333[bc]
40	66.1667[ab]
100	45.5000[c]

p=0.0003*

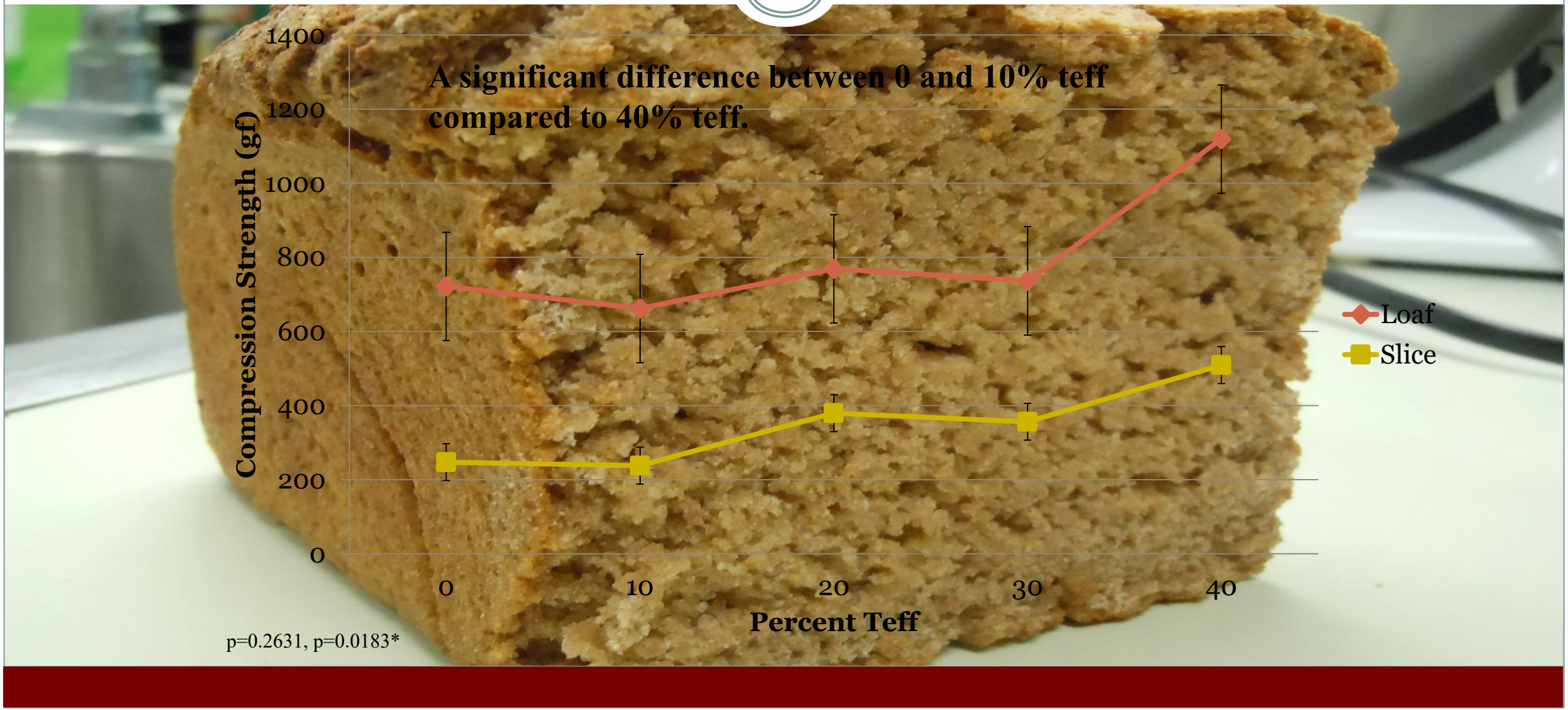
Bread Texture

The test produces a force-time graph that displays the magnitude of resistance to deformation for each sample.



Texture analysis of baked samples were measured using the Shimadzu EZ Test Texture Analyzer (Shimadzu 1875)

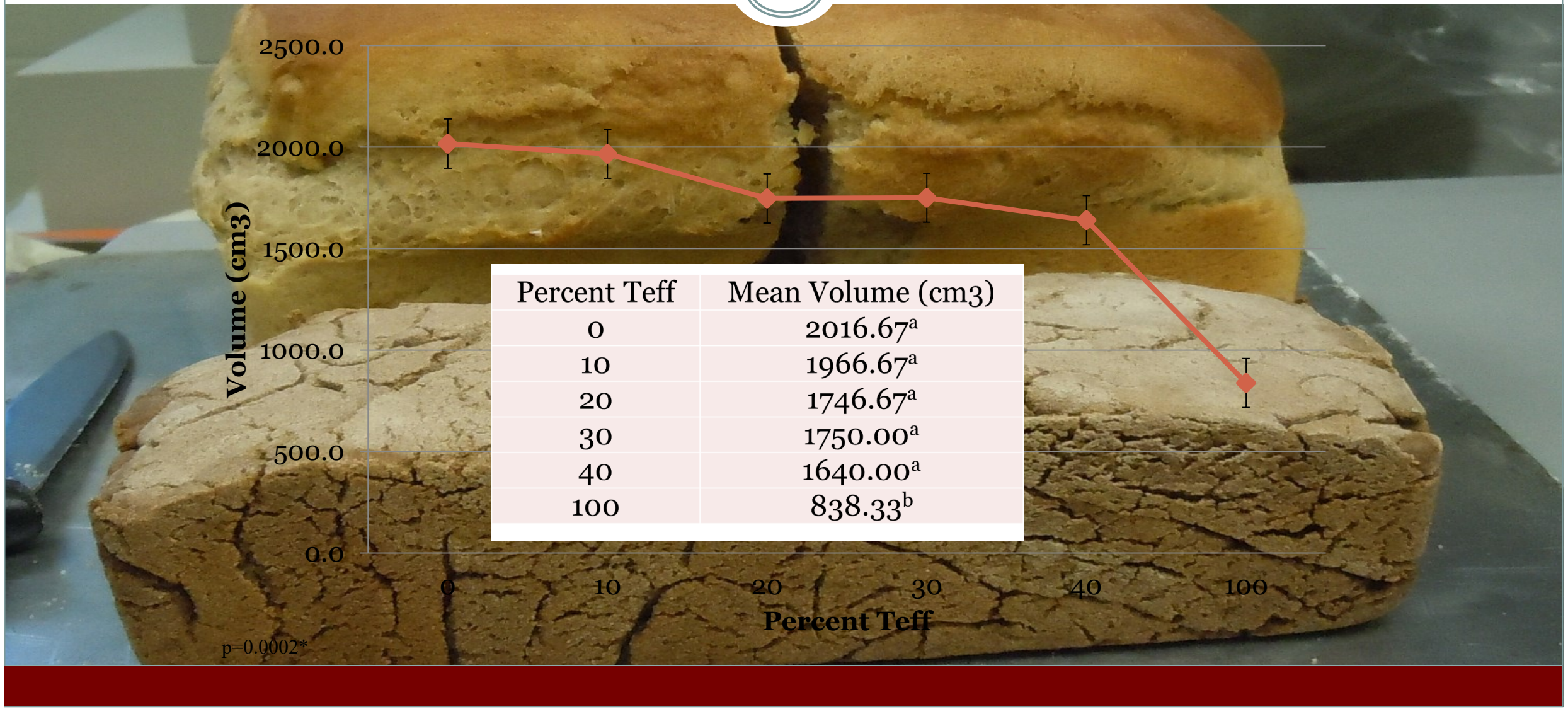
Bread Texture



Teff Bread

Bread Volume

Bread Volume



Percent Teff	Mean Volume (cm3)
0	2016.67[a]
10	1966.67[a]
20	1746.67[a]
30	1750.00[a]
40	1640.00[a]
100	838.33[b]

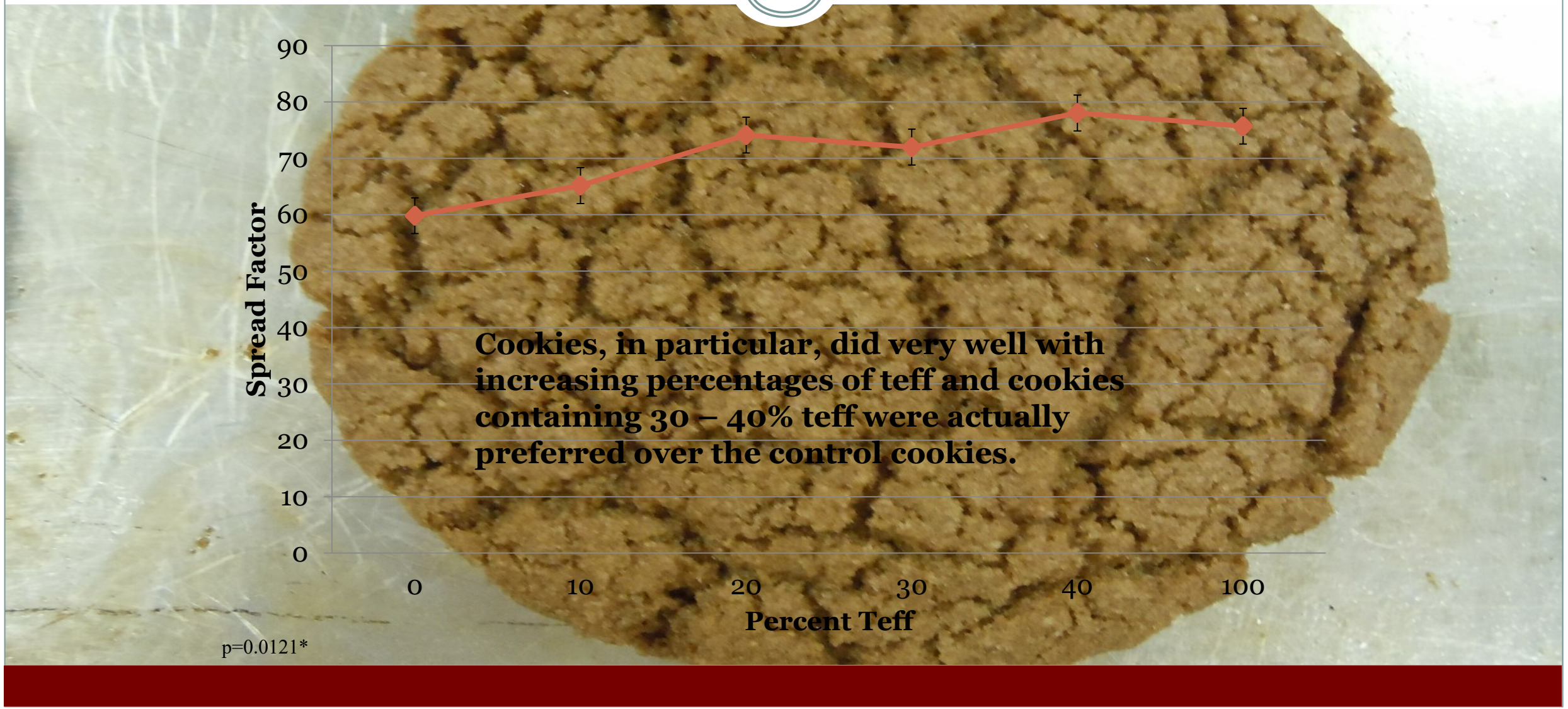
Teff Biscuits

Cookie Spread Factor

“A measurement used to define cookie quality and is the ratio of width to thickness (W/T).” (International 2009)

Teff Cookies

Cookie Spread Factor



Rosemary Parmesan Teff Crackers

Teff Crepes

Amino Acid Profile

Amino Acid Profile	Control Teff [a]	Brown Teff [a]	White Teff [a]	Barley [b]	Corn [b]	Oats [b]	Whole Wheat [b]	Wheat [b]	Teff [c]
Aspartic Acid	0.61	0.68	0.79	0.619	0.655	1.448	0.722	0.416	0.82
Threonine	0.37	0.46	0.51	0.337	0.354	0.575	0.367	0.269	0.51
Serine	0.4	0.49	0.54	0.418	0.447	0.75	0.62	0.494	0.622
Glutamic Acid	2.34	3.12	3.4	2.588	1.768	3.712	4.328	3.33	3.349
Proline	0.49	0.62	0.69	1.178	0.822	0.934	2.075	1.146	0.664
Glycine	0.32	0.35	0.39	0.359	0.386	0.841	0.569	0.356	0.477
Alanine	0.51	0.61	0.7	0.386	0.705	0.881	0.489	0.317	0.747
Valine	0.49	0.62	0.69	0.486	0.477	0.937	0.564	0.397	0.686

Amino Acid Profile

Amino Acid Profile	Control Teff [a]	Brown Teff [a]	White Teff [a]	Barley [b]	Corn [b]	Oats [b]	Whole Wheat [b]	Wheat [b]	Teff [c]
Cystine				0.219	0.17	0.408	0.275	0.21	0.236
Methionine				0.19	0.197	0.312	0.228	0.175	0.428
Isoleucine	0.38	0.48	0.54	0.362	0.337	0.694	0.443	0.342	0.501
Leucine	0.76	0.96	1.07	0.673	1.155	1.284	0.898	0.68	1.068
Tyrosine	0.42	0.53	0.58	0.284	0.383	0.573	0.275	0.298	0.458
Phenylalanine	0.52	0.66	0.75	0.556	0.463	0.895	0.682	0.498	0.698
Lysine	0.29	0.29	0.35	0.369	0.265	0.701	0.359	0.219	0.376
Histidine	0.23	0.26	0.29	0.223	0.287	0.405	0.357	0.22	0.301
Arginine	0.45	0.47	0.51	0.496	0.47	1.192	0.648	0.399	0.517

Sources: [a]Medallion Labs 2012, Samples produced in Virginia, [b]Nutrient Data Laboratory 2005, [c]National Agricultural Library 2011

Nutrient Profile

Analysis	Control Teff [a]	Brown Teff [a]	White Teff [a]	Barley [b]	Corn [b]	Oats [b]	Rice [b]	Wheat [b]	Teff [c]
Moisture (2-stage) (g)	9.25	8.8	8.2	10.09	10.37	8.22	11.89	10.59	8.82
Ash (As Is) (g)	2.767	2.037	2.403	1.11	1.2	1.72	0.61	4.33	2.37
Protein N x 5.7 (As Is) (g)	10.77	12.87	14.19						
Fat by GC:	-	-	-	-	-	-	-	-	-
Fat (Total) (As Is) (g)	3.045	2.726	2.868	1.16	4.74	6.9	1.42	0.97	2.38
Fat (Saturated) (As Is) (g)	0.753	0.73	0.789	0.244	0.667	1.217	0.386	0.154	0.449
Trans Fatty Acids (g)	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fat (Polyunsaturated) (g)	1.541	1.338	1.362	0.56	2.163	2.535	0.379	0.41	1.071
Fat (Monounsaturated) (g)	0.751	0.658	0.717	0.149	1.251	2.178	0.442	0.086	0.589
Carbohydrates (g)	74.17	73.57	72.34	77.72	74.26	66.27	80.13	74.22	73.13

Sources: [a]Medallion Labs 2012, Samples produced in Virginia, [b]Nutrient Data Laboratory 2005, [c]National Agricultural Library 2011

Nutrient Profile

Analysis	Control Teff [a]	Brown Teff [a]	White Teff [a]	Barley [b]	Corn [b]	Oats [b]	Rice [b]	Wheat [b]	Teff [c]
Calories	330.84	333.24	335.81	353	365	389	366	354	367
Calories from Fat	27.41	24.53	25.81						
Total Dietary Fiber (As Is) (g)	11.86	10.79	11.23	15.6	7.3	10.6	2.4	2.7	8
Fiber, Soluble (As Is) (g)	2.78	1.53	2.19						
Fiber, Insoluble (As Is) (g)	9.08	9.26	9.03						
Total Sugar (g)	3.3	1.6	4.2	0.8	0.64		0.12	0.22	1.84
Cholesterol (mg)	0.38	0.41	0.51	0	0	0	0	0	
Vitamin A (Iu)	ND	ND	ND	22	214	0	0	0	9
Ascorbic Acid (mg)	ND	ND	ND	0	0	0	0	0	
Calcium (mg)	203.5	188.5	182	29	7	54	10	338	180
Iron (mg)	15.1	12.8	18.9	2.5	2.71	4.72	0.35	4.67	7.63
Sodium (mg)	6	ND	ND	9	35	2	0	1270	12

Sources: [a]Medallion Labs 2012, Samples produced in Virginia, [b]Nutrient Data Laboratory 2005, [c]National Agricultural Library 2011

Can we go Teff in Virginia?...
Yes!

but there are still many challenges...

1. Effective weed control methods
2. Successful establishment (control of seeding depth and seed-to-soil contact)
3. Higher yielding varieties (grain type) suitable to Virginia's growing conditions
4. More effective and reliable harvesting and threshing methods


Seed-to-soil contact is essential!


Seeding into high crop residue
does not work

Tilling and/or herbicide is important for weed control

Irrigation may be necessary for initial germination…

Lodging

Concluding Thoughts

- **High initial investment**
- **Highly variable results**
- **Cooking characteristics:**
  - **Possible to bake cakes and bread with lower percentages of teff, but the quality of the final product was severely impaired at higher concentrations of teff flour.**
  - **<u>Biscuits and cookies were teff's more promising products.</u>**
  - **Cookies, in particular, did very well with increasing percentages of teff**
    - **Cookies containing <u>30 – 40% teff</u> were preferred over the control cookies.**
  - **None of the baked goods produced an acceptable product using 100% teff flour.**
- **Nutritionally valuable**

Thank you!

Eat More Teff!

Questions?