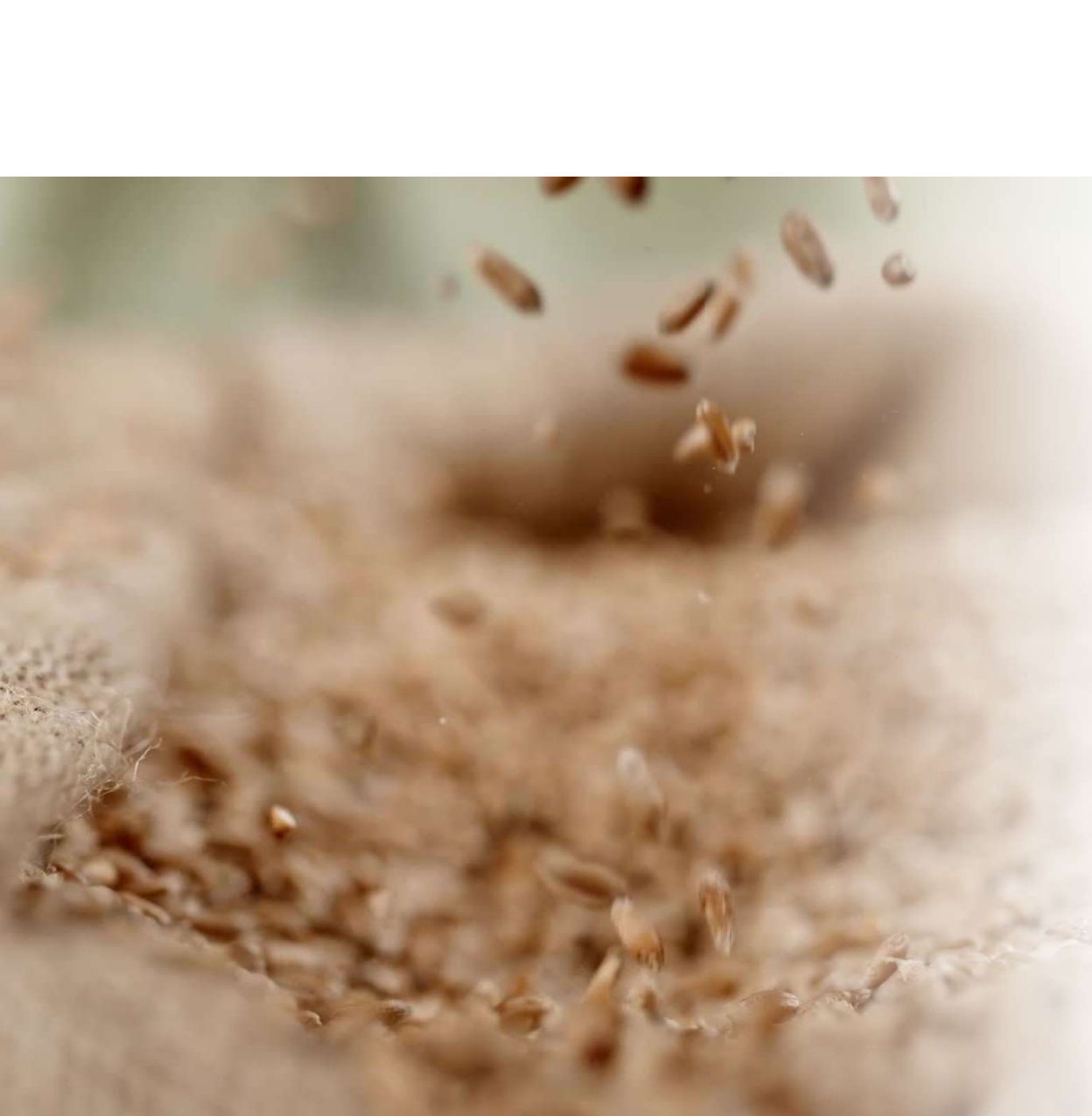


A close-up, shallow depth-of-field photograph of a burlap sack filled with wheat. Numerous wheat grains are captured in mid-air, falling from the top of the frame towards the bottom. The grains are golden-brown and have a distinct awn. The background is a soft, out-of-focus light brown, suggesting the interior of the sack or a similar environment. The lighting is natural and soft, highlighting the texture of the grains and the coarse weave of the sack.

Foldability Challenges for Gluten- Free (GF) Tortillas

David Ovadia, PhD

MOAT Consultancy

September 29, 2026

The Challenge of GF Tortilla Foldability

Wheat flour tortillas fold well when making burritos.

Gluten functionality in tortillas enables this good foldability.

Gluten-free (GF) tortillas often crack or break when folded.

How can we make GF tortillas that do **not** crack or break?

Cryogenic Freezing of Wheat Flour

An inventor persuaded my company president:

Wheat flour frozen to -320°F (-196°C) will be “Celiac-Safe”

Scientists in the US and around the world told me:

“Cryogenic freezing *will not* make wheat flour Celiac Safe.”

I told this to the company president.

Can't Get No Respect

He told me: “Go and check it out anyway.” “Yes, Sir,” I responded.

70 lb (32 Kg) flour samples were frozen in liquid nitrogen to -320°F (-196°C).

NDSU proved these frozen flour samples still made good bread.

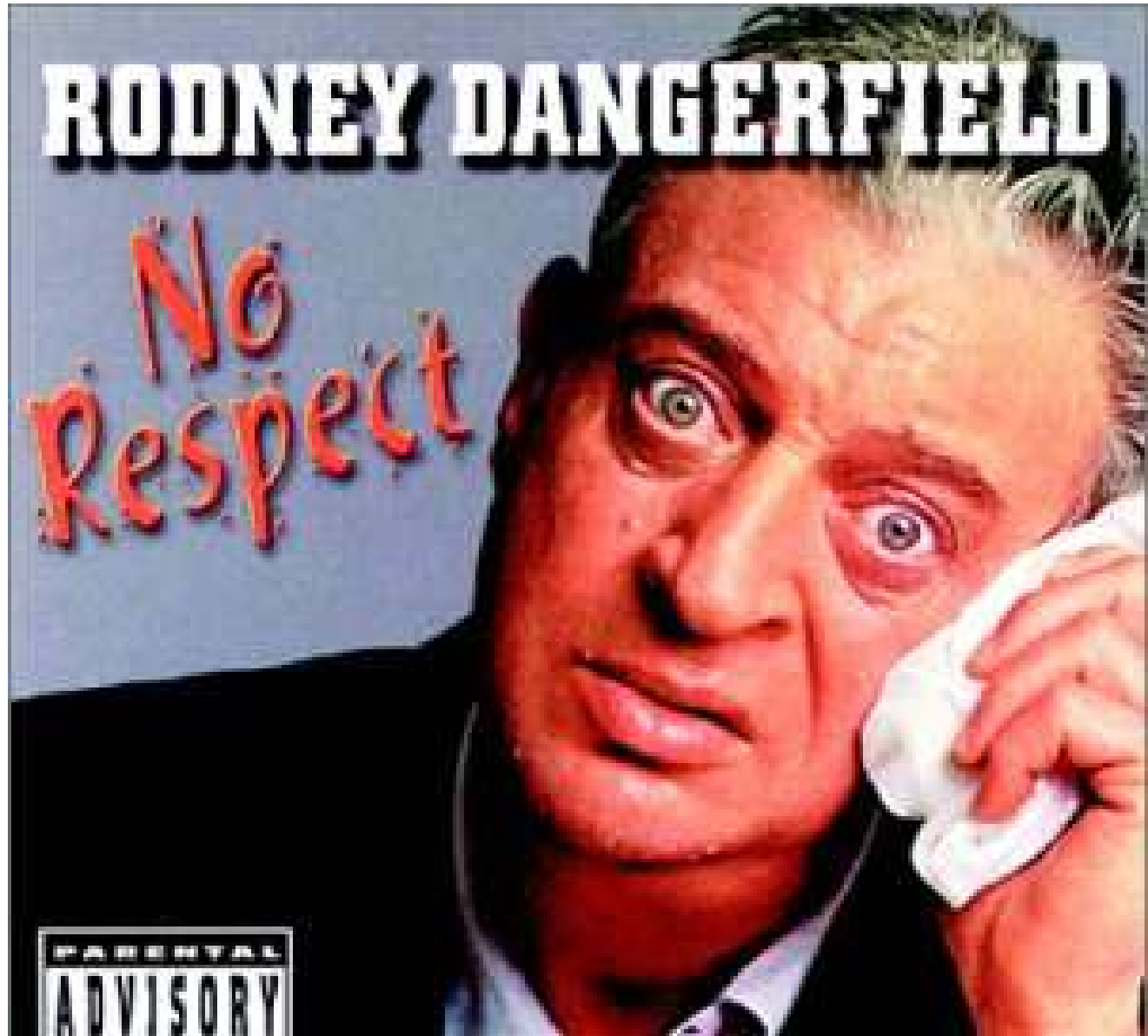
FARRP at the U. Nebraska proved the flour was ***not*** Celiac-Safe

- (FARRP: Food Allergen Research & Resource Program)

Cryogenic freezing did ***not*** help – my expert opinion fell on deaf ears.

I felt like Rodney Dangerfield:

Figure 1.
Rodney
Dangerfield –
“I Can’t Get No
Respect!”



If not Cryogenic Freezing – What Might Work?

To answer that question, let's look at gluten

```
graph TD; A[To answer that question, let's look at gluten] --> B[Gluten provides flexibility/elasticity to tortillas.]; B --> C[If we take out gluten, how can we replace it?]; C --> D[Are there cost-effective replacements?]; D --> E[Is there a good supply of these replacements?];
```

Gluten provides flexibility/elasticity to tortillas.

If we take out gluten, how can we replace it?

Are there cost-effective replacements?

Is there a good supply of these replacements?

Figure 2. What is Gluten?

- Gluten is a protein located in the endosperm within grass-type grains such as wheat, barley and rye
- It's actually a combination of 2 proteins: Gliadin and Glutenin

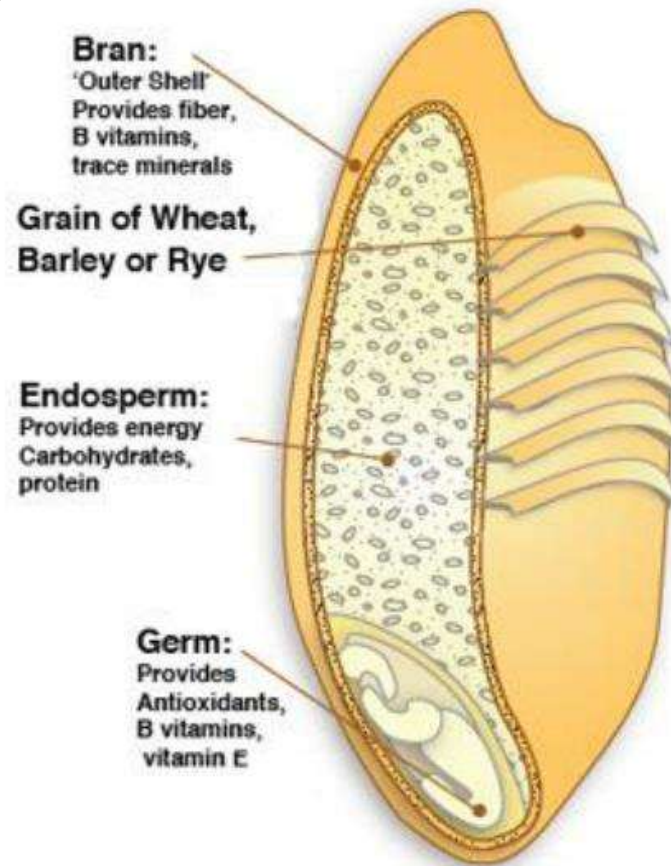
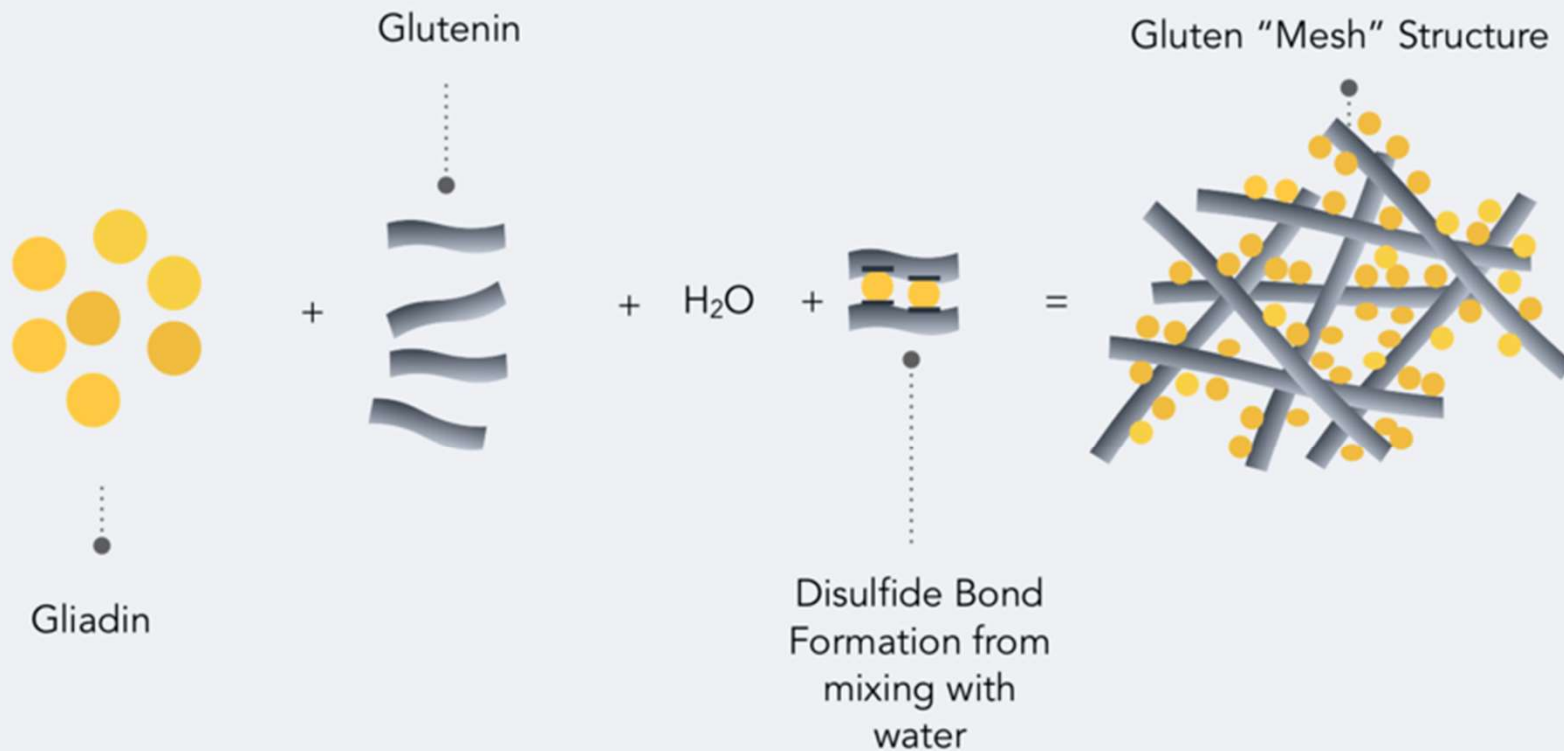


Figure 3. [Glutenin + Gliadin] in Flour Mixed with Water = Gluten



The Gluten Matrix of Wheat Flour Dough

When water is mixed with wheat flour, something remarkable happens.

Trillions of gluten tendrils reach out like creatures from outer space.

They bind together and create a 3-D network: ***the continuous gluten matrix.***

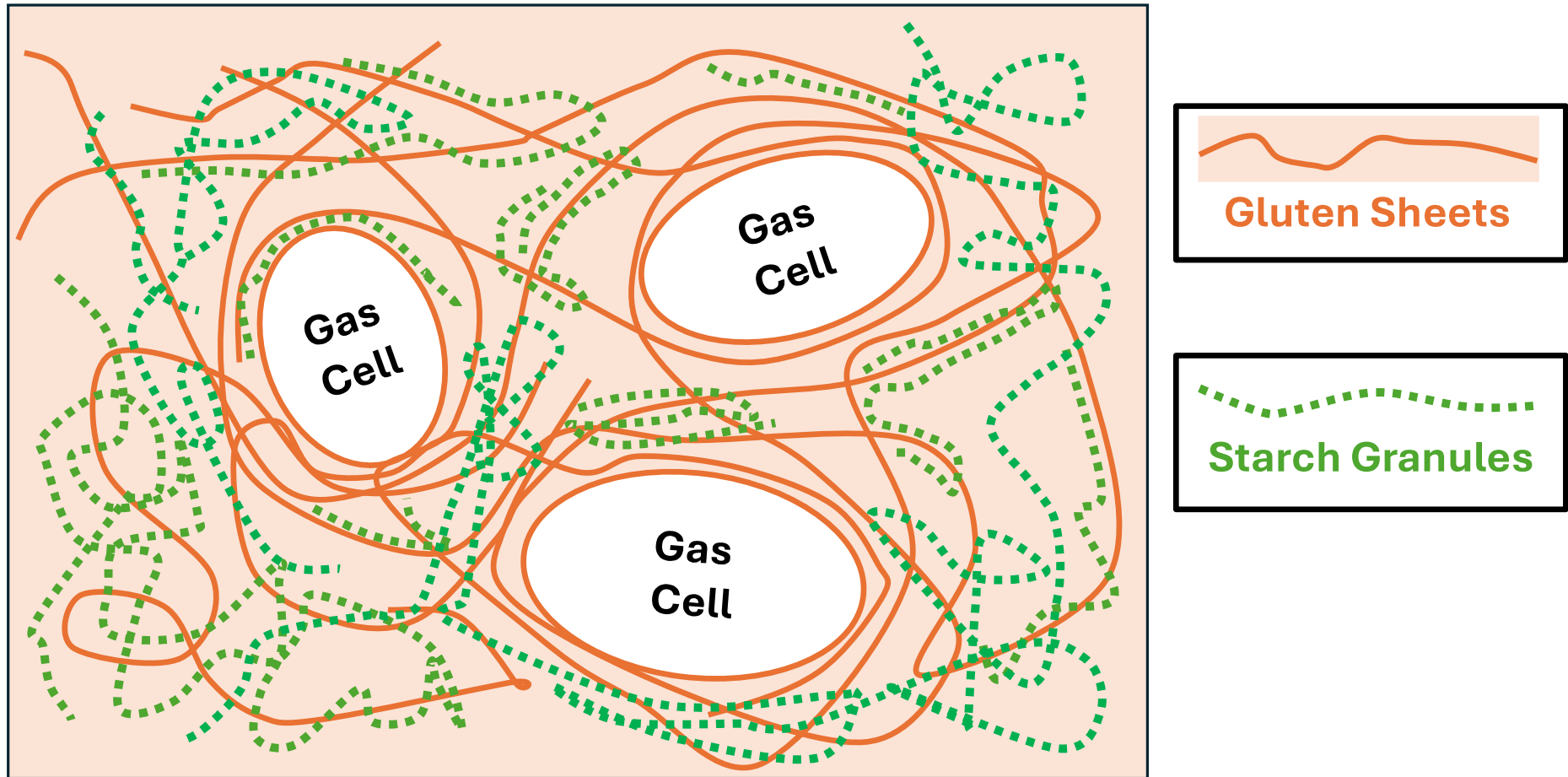
- **Gluten tendrils join and form microscopic elastic sheets + gas cells (tiny balloons).**

70% of the wheat endosperm dry matter is starch.

But 15% gluten dominates tortilla microstructure.

Gluten matrix dominates tortilla microstructure: this provides foldability.

Figure 4. Continuous Gluten Matrix in Dough



Gluten Crosslinking & Foldability

Gluten polymer crosslinking is essential to foldability - enabled by:

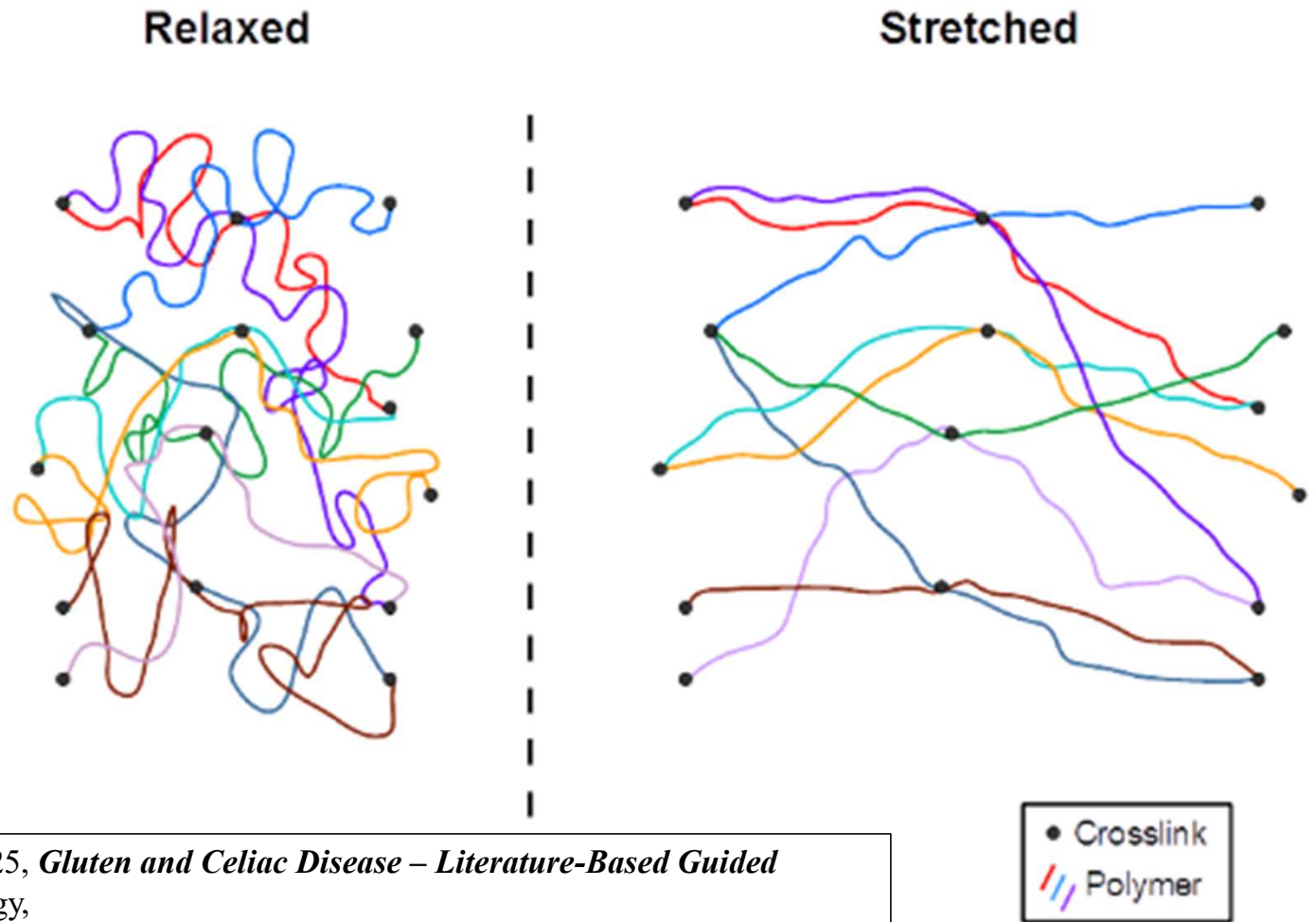
- **(1) Disulphide bonds** between **2 cysteine peptides**: they occur naturally.
 - Can be optimized by adding cysteine, ascorbic acid and xylanase enzymes.
- **(2) Dityrosine bonds** between **2 tyrosine peptides**: they occur naturally.
 - Can be optimized by adding peroxidase enzymes.
- **(3) Transglutamine bonds** between **1 lysine & 1 glutamine peptide**:
 - These crosslinks are “man made” by adding transglutaminase (TGase) enzymes.

In GF doughs, gluten and its crosslinking is lost.

Figure 5 sketches how gluten crosslinking makes dough elastic.

- It acts like a rubber band.

Figure 5. Gluten Polymer Crosslinks Enhance Flexibility



From: Jakubowski, H., and Flatt, P., 2025, *Gluten and Celiac Disease – Literature-Based Guided Assessment (LGA)*, LibreTexts™ Biology,
https://bio.libretexts.org/Workbench/LGA_Masters/01%3A_First_Chapter/Gluten_and_Celiac_Disease.

Celiac's Disease Caused by **Gliadin**

Gluten in wheat-flour-dough makes tortillas foldable.

But gliadin (30% of gluten) causes Celiac's disease because:

Gliadin polymers possess polypeptide strings of 33 peptides:

... -(LQLQPFPQPQLPYPQPQLPYPQPQLPYPQPQPF)- ...

L = Leucine, Q = Glutamine, P = Proline, F = Phenylalanine, Y = Tyrosine

That string causes an auto-immune response in Celiac sufferers.

Foldable GF Tortillas

How can we eliminate wheat gliadin?

Without gliadin, how can we still make foldable tortillas?

Can genetic engineering of wheat eliminate gliadin?

Some grains do not contain gliadin and are GF:

- Corn, rice, oats, sorghum, millet, teff.

But can GF grains without gliadin make foldable tortillas?

Options to Enhance GF Tortilla Foldability

We will look at three options to enhance GF foldability:

(A) Modifying wheat to become “Celiac-Safe”

- **But still deliver good tortilla foldability**

(B) GF grain proteins modified to function like gluten

(C) Other novel approaches

A1: Solutions for Modified Wheat

There are at least two ways to make wheat Celiac-Safe:

(1) Cleave gliadin with protease enzymes:

- Celiac-Harmful gliadin **can** be cleaved by enzymes.
- This gluten degradation makes flour Celiac-Safe.
- But it creates flour that is **useless** for making bread and tortillas.

(2) Wheat genetically engineered to exclude gliadin

- This is a distinct possibility based on research so far.
- Work started at Washington State University (WSU) 18 years ago.

A2: Wheat's Genome (Genetic Blueprint)

Wheat's genome *can* be engineered to exclude harmful gliadins.

- It would be Celiac-Safe **and** retain glutenin (not gliadin) for foldable tortillas.

Work *so far* indicates this wheat flour will make good tortillas

Further progress is needed and it faces major challenges

The wheat genome is 5-6 times larger than the human genome

This makes it extremely hard to eliminate gliadin completely.

Sadly, the champion of this project at WSU is no longer with us.

- He was the “Albert Einstein” of plant genetics



Figure 6.
Dr. Diter von Wettstein
Distinguished Plant Geneticist
(1929-2017)

-
- Dr. Wettstein started developing Celiac-Safe wheat at Washington State University in 2008.
 - Initial indications are promising – good bread-&-tortilla-making-flour can be obtained this way.
 - In 2013, he told me this will take another 10-20 years to complete.
 - However, since he passed away in 2017, this work at Washington State has been discontinued.

B1: GF Grain Proteins for Making Foldable Tortillas

Can GF grain proteins of corn, teff, etc., be used to make bread?

Can their proteins yield foldable tortillas?

If not as-is, can GF grain proteins be modified to act like gluten?

If they have already been modified to perform like gluten -

What is the current state-of-the-art?

B2: Grain Storage Proteins: “Prolamins”



All grain endosperms store protein+starch for initial plant growth



Grain storage proteins are called “prolamins”



Wheat **prolamin** is the problematic **gliadin** that Causes Celiac's Disease



Prolamins of some GF grains are already extracted commercially:

But can they replace the foldability function of gluten (which contains gliadin)?

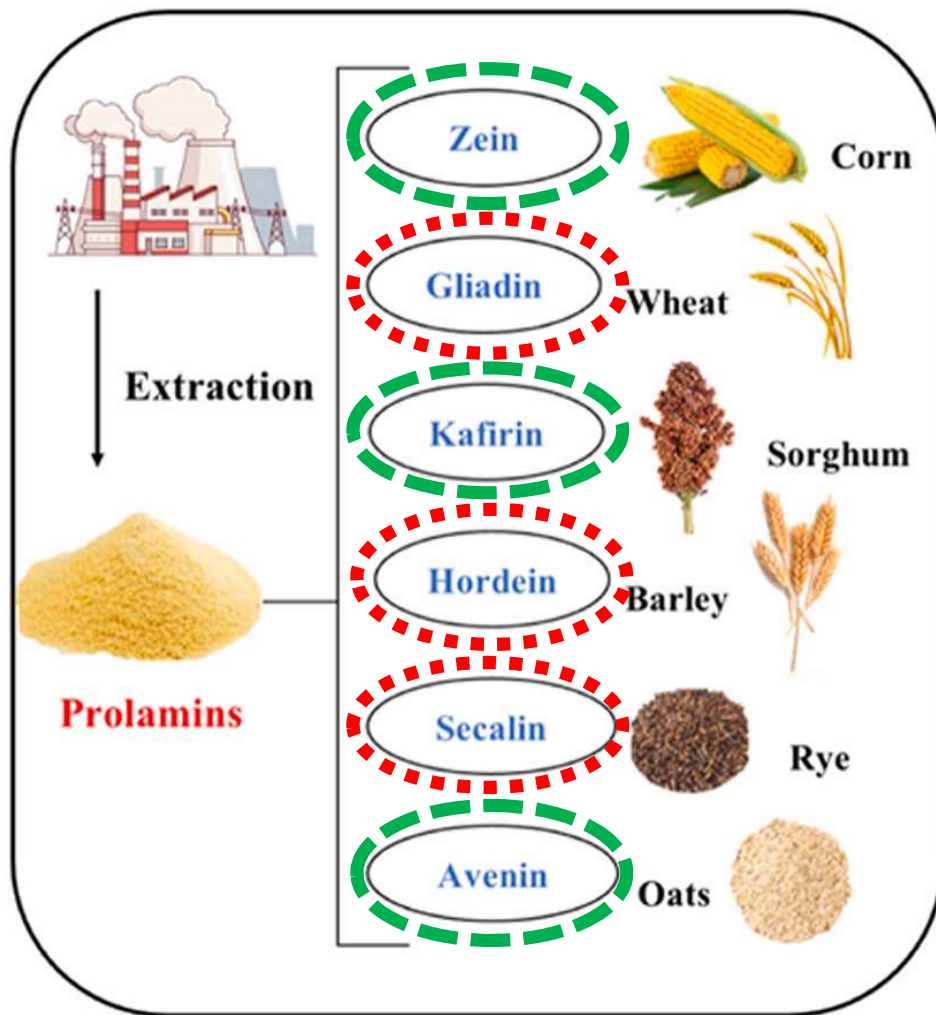


Figure 7. Prolamins Extracted Commercially:

- Zein and kafirin are promising gluten-replacers for foldability in tortillas, **but not avenin**.

Celiac Safe

Celiac Unsafe

Drawing based upon: Graphical Abstract of Xinmei, S., Sun, H., Li, Y., Zhang, H., & Yang, R., April 2024, The Prolamins, from Structure, Property, to the Function in Encapsulation and Delivery of Bioactive Compounds, Food Hydrocolloids, Vol. 149, April 2024, 109508 (<https://doi.org/10.1016/j.foodhyd.2023.109508>)

B3: Zein from Corn for Foldable Tortillas

There are several advantages of zein.

Corn is readily available as an inexpensive grain.

Zein is already extracted on an industrial level.

Moist corn tortillas today are also readily available.

- But they crack and split when folded.

Can zein be made to act like gluten for foldable GF tortillas?

B4: Research into Modified Zein

Research shows: zein *could* make tortillas more foldable.

However, zein needs to be modified to behave like gluten.

Currently, the modification process is cost-prohibitive.

Also, zein-enhanced elasticity is not as good as gluten.

Work is needed to reduce cost and increase elasticity.

B5: Kafirin, the Prolamin of Sorghum

Sorghum's kafirin has also been researched to replace gluten.

Kafirin is hard to process for food applications.

- It is also hard to digest when consumed.

Kafirin has not yet been widely-commercialized.

It is not yet as fully-functional as a gluten substitute.

More work is needed to modify kafirin so it can replace gluten.

B6: Prolamins of Other GF Grains

Can we consider GF prolamins of rice, oats, millet, and teff?

Rice possesses little ($\approx 3\%$) of its prolamin, oryzenin, and is not viable.

Oat prolamin, avenin, is too unlike gluten to replace it.

Oats often contaminated with Celiac-Unsafe wheat, barley, & rye:

- Contamination happens during growing, harvesting, transportation, and milling.

Millet and teff prolamins have not yet been investigated.

C1: Ancient GF Flatbreads

Flatbreads have been made from grains for thousands of years.

Some are made from GF grains teff, millet, sorghum, corn, rice.

Ethiopian injera sourdough flatbread is flexible and foldable.

Injera is made from teff flour, water, and salt.

Can we use injera as foldable tortilla?

Can we learn from injera to develop other foldable GF tortillas?

C2: More About Injera

Injera is a foldable Ethiopian GF sourdough flatbread.

It serves as an edible dinner plate, like pizza.

Rolled-up injera strips are also used to scoop up food

These strips of injera serve as eating utensils.

Injera is made like a crepe from batter fermented 1-4 days.

Figure 8. Teff-Based Ethiopian Flatbread – Injera



Injera

Figure 9. Teff-Based Ethiopian Flatbread – Injera



Injera

C3: Injera – Teff Availability and Cost

However, teff flour is expensive (\$17/lb, or, \$37/Kg).

Teff is a low-yielding crop of tiny grains.

Supply might be a problem – teff is not extensively grown.

Fermenting batter 1-4 days is a manufacturing challenge.

- But fermentation may be critical in creating injera's flexibility.

C4: Other GF Grains Used to Make Injera

Injera can also be made from millet, sorghum, corn or rice.



If teff is replaced by other GF grains - is injera's foldability lost?



Perhaps we can also learn from other ancient GF flatbreads.

C5: Other Ancient GF Flatbreads

Other GF flatbreads might help us develop foldable tortillas:

(1) Jowar Roti in India made from sorghum.

(2) Ragi Roti millet flatbread from South India.

(3) Andalusian Millet Bread from Southern Spain.

(4) Indian Millet Dosa uses finger millet + horse gram grains.

C6: A Different Approach

My work on GF tortillas with cauliflower yielded an idea.

People eat the white “crown” but discard the leaves and stalk.

Why not shred them fine and mix them into GF tortilla dough?

- Shreds can form a gluten-like matrix for flexible tortillas

These shreds use a discarded raw material with a health halo

- This is an inexpensive, marketable “made-with-cauliflower” ingredient

It yields a functional replacement for gluten (WO 2025/080355 A1).

Conclusions - 1

We want GF tortillas to be more foldable for making burritos.

Foldability comes from **gluten (gliadin+glutenin)** in wheat.

Celiac-Harmful gliadin can be genetically engineered out of wheat

- But would require 10-20 more years and a scientist like the late Dr. Wettstein

GF zein from corn can be modified to act somewhat like gluten

- But processing is cost-prohibitive and its gluten-like flexibility is limited.
- More work is needed.
- This is also the case for sorghum's kafirin protein.

Conclusions - 2

GF grain proteins from teff and millet have not been investigated

- Maybe they could yield promising results.

Ethiopian injera using GF teff might yield a foldable tortilla

- Teff flour costs \$17/lb (\$37/Kg) and is not readily available.
- But injera can be made from cheaper GF grains (e.g., millet, corn, sorghum)
- Maybe these can yield affordable, foldable injera and tortillas.
- Other ancient GF flatbreads, not just injera, might yield opportunities.

Shredded cauliflower stalks might replace gluten in GF tortilla

Are there any questions?



References - 1

- Belakireva, A.V., Zamyatnin Jr., A.A., 2016, *Properties of Gluten Intolerance: Gluten Structure, Evolution, Pathogenicity and Detoxification Capabilities*, 2016, Nutrients 2016, 8, 644; <https://doi:10.3390/nu8100644>, www.mdpi/journal/nutrients.
- CAHNRS Communications, April 23, 2008, *Von Wettstein Receives NIH Award to Develop Wheat Free of Harmful Gluten Proteins*, <https://news.cahnrs.wsu.edu/article/von-wettstein-receives-nih-award-to-develop-wheat-free-of-harmful-gluten-proteins/>
- Diatta, A., 2018, *Using Corn to Improve the Quality of Gluten-Free Bread*, MS Thesis, Purdue University, Department of Food Science, https://docs.lib.purdue.edu/open_access_theses/1447.
- Hooper, J.H., 2017, *Diter von Wettstein (Dietrich Holger Wettstein Ritter von Westerheim): September 20, 1929 – April 13, 2017*, Photosynth Res. 2017;134(1) : <https://doi:10.1007/s11120-017-0420-9>. Epub 2017 Jul 25. PMCID: PMC5603627.
- Jakubowski, H., and Platt, P., 2025, *Gluten and Celiac Disease – Literature-Based Guided Assessment (LGA)*, LibreTexts™ Biology, https://bio.libretexts.org/Workbench/LGA_Masters/01%3A_First_Chapter/Gluten_and_Celiac_Disease.
- Khalid, W., Arshad, M.J., Aslam, N., Mukhtar, S., Rahim, M.A., Ranjha, M.M.A.N, Noreen, S., Afzal, M.F., Aziz, A., and Awuchi, C.G. 2022. *Food Applications of Sorghum Derived Kafirins Potentially Valuable in Celiac Disease*, *International Journal of Food Properties*, 2022, Vol. 25, No. 1, 2348-2362, <https://doi.org/10.1080/10942912.2022.2135532>.

References - 2

- Kumar, V. Sharma, C., Bhatt, S.C., Rajput, V., Mishra, R., Gupta, A.K., Shika, D., Kumar, V., and Naik, B., 2026, ***Fermented Millets as Next-Generation Functional Foods: Insights into Microbiota Modulation and Gastrointestinal Health***, Food Production, Processing and Nutrition (2026) 8:54, <https://doi/10.1186/s43014-026-00402-y>.
- Mesa-Stonestreet, N.M., Alavi, S., and Bean, S. 2010, ***Sorghum Proteins: The Concentration, Isolation, Modification, and Food Applications of Kafirins***, Journal of Food Science Vol. 75, Nr. 5, 2010. <https://doi: 10.1111/j.1750.2020.01623.x>.
- Ovadia, D.Z., 2025, ***Vegan Lo-Carbohydrate Gluten Replacer and Food Compositions and Products Containing the Same***, WO 2025/080355 A1
- Raza, H., Pasha, I., Shoaib, M. Zaaboul, F., and Aboshara, W. 2017, ***Review of the Functional and Rheological Attributes of Kafirin for Utilization in Gluten Free Baking Industry***, American Journal of Food Science and Nutrition Research, 2017; 4(5): 150-157, <http://www.openscienceonline.com/journal/fsnr>.
- Sha, X., Li, Y., Wu., J., Zhang, H., Yang, R., 2024, ***The Prolamins, from Structure, Property, to the Function in Encapsulation and Delivery of Bioactive Compounds***, Food Hydrocolloids, Vol. 149, April 2024, 109508, <https://doi.org/10.1016/j.foodhyd/2023.109508>.
- Zhang, Y., Xu, M., Zhang, X., Hu, Y., and Luan, G., 2022, ***Application of Zein in Gluten-Free Foods: A Comprehensive Review***, Journal of Food Research International <https://doi/10.1016/j.foodres.2022.111722>.