

Dry and Wet Milling Process

Unit 2 Lesson 4

Precepts

A. Action
A5. Communicate effectively with others.

National Standards

NL-ENG.K-12.4. Communication Skills.

Student Learning Objectives

As a result of this lesson, the student will …
1. Describe the steps in the dry-milling process.
2. Describe the steps in the wet-milling process.
3. Recognize the final product of ethanol production and the by-products.

Time

Instruction time for this lesson: 90 minutes.

Resources

http://www.cleanfuelsohio.org
http://people.hws.edu/environmentalstudies/Ethanol%20Info/Wet%20Mill.html

Tools, Equipment, Supplies

Writing surface
Projector
TM.A
TM.B
TM.C
AS.A - one per student
AS.B - one per student
AS.C - one per student
Assess.A - one per student
Miniature marshmallows
Toothpicks- one box per group
Plastic Bags

Key Terms

The following terms are presented in this lesson and appear in ***bold italics***:
Dry-milling
Milling
Liquefaction
Saccharification

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Fermentation
Distillation
Dehydration
Denaturing
Wet-Milling

INTEREST APPROACH

Students will need to be in groups of four to five students for this activity. The easiest way to divide students into groups is to have the students count off. To do this, determine the total number of students and divide by four or five. This will give you an idea of how many groups you will need. When the students are counting, have them count off according to the number of groups needed.

Once the students are in their groups, give each group a plastic bag that has miniature marshmallows and a box of toothpicks in it. Students will be working in groups to create the tallest freestanding tower using the marshmallows and the toothpicks. Do not give them time to develop a plan. Have them start their tower as soon as they get their supplies.


When I say, "Go", each group will receive a bag of supplies. With the supplies we are given, our group's task is to build the tallest freestanding tower. What does freestanding mean? *Allow an opportunity for students to respond.*
That's right. Nothing can be supporting the tower. You can't hold the tower, push it up against something, etc.

We will only have three minutes to build the tower, so as soon as your team receives their supplies, you will need to work as quickly as possible. Questions? Go!

Give each group their supplies and let them get to work. As they are building, it will be important to monitor their progress and give them ideas if they need them. Make sure the structures are freestanding and keep a close track of time.

Once time is up see which group had the tallest tower, and give them a round of applause.


Time's up! Let's check out how we did. *Determine which group has the tallest tower.* Looks like we have a winner! Congratulations. Let's give this group a round of applause. *When you have determined a winner, it would be helpful to gather all the trash and throw it away at this point.*

Think about this for a moment…how did you determine a strategy for building the tower? Who will describe to us how their group decided to build their tower? *Elicit student responses.* Excellent! Thanks for sharing. Who will share next? *Elicit student responses.*

Even though the end product was the same, the process used to create the end product was much different.

Let's think of another example... pretend we are taking a trip. We all have the same starting point and the same destination point. Even though we MIGHT take the same roads, we could all take a different route and end up at the same spot. Does this make sense?

We can apply this concept to ethanol production as well. When working towards the production of ethanol producers can use one of two processes, a ***dry-milling*** process or a ***wet-milling*** process. Today, we will examine both processes and identify the differences in each process. As we begin

our lesson today, I challenge you to critically examine both processes to determine which you think is more practical and beneficial.

OBJECTIVE 1. Describe the steps in the dry-milling process.

*To best explain the difference between the **dry-milling** and **wet-milling** process, each step will be explained in detail. Provide AS.A for each student. This activity sheet lists the steps of the **dry-milling** process, describes the process, and then has a column for the students to draw an icon or picture that represents that step.*

Use the Little Professor Moment to engage the students in the content. Follow these steps to complete the activity. The content is located on AS.A.

1. *Chunk your content. Determine the portions of information. Make the portions uniform both in amount and number so that the time spent teaching each group of students is approximately the same.*

2. *Establish roles. Each student exhibits two roles—one while they are taking notes and one while they wait. While they learn from you, they are eager learners, full of wonder and interest. While they wait, they are the "invisible person," neither sitting still and neither moving nor speaking. Note: Some students may find being "invisible" too challenging. Instead of sitting still and silent, they can read.*

3. *Establish personas. Review with students the characteristics of a stereotypical university professor. As they teach the new material they act as if they have their PhD in the subject area, and from this point forward are referred to by their peer as Dr. (fill in their last name). For ease of teaching, address the first student in each pair as Little Professor I and the second student as Little Professor II.*

4. *Teach the first chunk. Little Professor I listens and takes appropriate notes. Keep this short and to the point. Little Professor I then teaches his or her partner. This is a timed event! Give them only 30 to 60 seconds to instruct. Before moving to the second chunk of information, check Little Professor II's understanding.*

5. *Teach the second chunk. Now it's Little Professor II's turn to take notes. Little Professor II will then teach his or her partner.*

6. *Repeat the cycle. Repeat steps for as many chunks of information there are.*

*When the steps of the **dry-milling** process have been explained using the Little Professor Moment, have each student draw a picture or icon in the appropriate column of AS.A to help them remember that information.*



First, let's examine the process of **dry-milling** corn to make ethanol. The steps are listed on the activity sheet you are about to receive.

I. The ***dry-milling*** process includes the following steps:

A. ***Milling***: After the corn, barley, or wheat is cleaned, it will past first through hammer mills which grind it into fine powder.

B. ***Liquefaction***: The meal will then be mixed with water and an enzyme called alpha-amylase, and will pass through cookers where the starch is liquefied. A pH of 7 is maintained by adding sulfuric acid or sodium hydroxide. Heat is applied to enable liquefaction. Cookers with a high temperature stage 120-150 degrees Celsius and lower holding period of 95°C will be used. The higher temperature reduces the bacteria in the mash.

C. ***Saccharification***: The mash from the cookers will be cooled and the enzyme gluco-amylase will be added to convert starch molecules to fermentable sugars or dextrose.

D. ***Fermentation***: Yeast will be added to the mash to ferment the sugars to ethanol and carbon dioxide. Using a continuous process, the fermenting mash will flow or cascade, through several fermenters until the mash is fully fermented and leaves the tank. In a batch fermentation process the mash stays in one fermenter for about 48 hours.

E. ***Distillation***: The fermented mash will then be pumped to the continuous flow, multi-column ***distillation*** system where the 10% alcohol will be removed from the solids and water. The alcohol will leave the top of the final column at about 96% strength, and the residue mash, called stillage, will be transferred from the base of the column to the co-product processing area.

F. ***Dehydration***: The alcohol will then pass through the dehydration system where the remaining water will be removed. Most plants use a molecular sieve to capture the last bit of water in the Ethanol. The alcohol at this stage is call anhydrous.

G. ***Denaturing***: Ethanol that will be used for fuel is then denatured with a small amount of some product like gasoline, to make it unfit for human consumption.

To help us recall what each steps means, think about a picture or icon that would illustrate that step. We will use the same activity sheet to draw an illustration or icon for each of the seven steps of the ***dry-milling*** process. If you need help coming up with an idea, please raise your hand and I will be around to help you. We will have eight minutes to complete this task. What questions are there?

While students are working, be sure to monitor their progress and offer assistance as needed. When time is up or students have finished, give them an opportunity to share their drawing with someone sitting near them.



Time is up! Let's see your illustrations for each step. Stand up! Find someone next to you to share your illustrations with. *Give time for students to share with a partner.* Tell your partner thanks! Good job!

Now that we have taken a look at the ***dry-milling*** process, let's examine the ***wet-milling*** process. Let your inquisitive minds motivate us to continue working hard!

OBJECTIVE 2. Describe the steps in the wet-milling process.

Write the following information on the writing surface or use TM.A. For this objective, have students only write down the first two bullets on TM.A. The next section will be written down using an activity.

II. ***Wet-milling*** process has many steps that can make it a costly but beneficial process.

A. Steps in ***wet-milling*** process. The wet milling process is a more intensive process than is normally used to produce ethanol, but it produces additional byproducts which can make this a more appealing process. The byproducts come as a result of breaking the corn into its four main components: starch, germ (the heart of a kernel of corn), fiber and protein.

To "gather" more of the content, use the Go-Get-It Moment. The Go-Get-It Moment is a brain-based activity that allows students to seek out information by kinesthetic or cognitive means. The teacher provides the information in various ways for students to seek out.

The materials for the Go-Get-It Moment are on TM.A. They are the six bullets under section "A". The statements will need to be cut out individually and posted around the room prior to teaching the lesson. It might be helpful to put the statements on brightly colored paper to help the students locate the information. Have the students take their notebooks and move around the room to locate the information. When they have found one statement, they will need to write it in their notebooks. They will need to follow this process for all of the statements.



Around the room, you will see six statements posted on brightly colored paper. When I say "move," you will have five minutes to make your way to all six of the papers and write down the information in your notebooks. Questions? Move!

As students are writing the information down, be sure to monitor their progress. When time is up or all students have finished, continue with the lesson.

1. First, the cleaned and inspected corn is steeped (soaked) for up to two days, which begins to break down the bonds holding the starch and proteins together.

2. The corn is then coarsely ground up to remove the germ from the rest of the components. The germ can be used to make corn oil, and the remainder of that process creates some feed products that can be given to livestock.

3. The corn, now in the form of slurry, is more finely ground. The fiber is then taken out using an attrition-impact mill. The fiber is used as a major element in animal feeds.

4. The starch and gluten are separated using a centrifuge to make the much denser starch fall to the bottom of the mix. The starch continues in the process towards becoming ethanol, while the gluten is used as another ingredient in animal feeds.

5. Water and enzymes are added that will ferment the starches into ethanol and other alcohols to the remaining starch. In creating the starch mixture, not all the starch can used, so some of the syrup ends up becoming high fructose corn syrup, a common inexpensive sweetener.

6. After fermentation, the alcohol mixture will be nearly ready to be used as an additive, and the CO_2 gas that has collected in the fermentation chamber can be collected and sold to soda companies for carbonation.

Write the following bullet on the writing surface or use TM.A. Have the students write this information in their notebooks.

B. The advantages of the wet milling process are easy to see with so many byproducts that can be sold to compensate for the cost of the process. However, wet milling is still not a perfect solution. Much of the machinery is more expensive than what is involved in dry milling and the dangerous chemical sulfur dioxide is used, which means additional safety steps much be taken in a wet milling plant.

*Using the AS.B which compares the **dry-milling** and **wet-milling** process. After giving students the opportunities to compare, emphasize that the **wet-milling** production process is a more elaborate and labor intensive operation. This operation is more labor intensive because it breaks down the entire corn kernel into its components, and then utilizes only the starch in the fermentation process. This differs from the **dry-milling** process, because in **dry-milling** the entire mash is fermented.*


Now that we have the steps of both **dry-milling** and **wet-milling**, let's compare them. You are receiving an activity sheet that compares the processes. When you have received the activity sheet, examine both processes and identify how they are different. What do you notice? *Give the students about two minutes to analyze the handout, and then have them share that information with a partner.*


Turn to a neighbor and share with them what you noticed about the differences between the two processes. *Allow students to share.* Who will share with the class what they noticed about the differences? *Elicit student responses.* Excellent! Thanks for sharing!

We know that the ethanol-based fuel is one product we use from the production of ethanol. But are there others? Let's take a closer look at the by-products that result from the production of ethanol.

Objective 3. Recognize the final product of ethanol production and the by-products.

Write the following information on the writing surface or use TM.C.

I. There are several byproducts from ethanol production.

A. Each bushel of corn (56lbs.) can produce up to 2.5 gallons of ethanol fuel

1. Only the starch from corn is used to make ethanol.

B. Most of the substance of the corn kernel remains, leaving the protein and valuable co-products to be used in the production of food for people, livestock, feed and various chemicals

1. Animal Feed: Feed grain for animals is produced from the residue left over after the production of the alcohol.

2. Corn syrup: An expanding market and the high cost of fructose corn syrup encouraged expansion of wet mill plants that produce the syrup as a by-product of the ethanol production process.

3. Corn gluten meal, which can be used as a natural herbicide or as a high protein supplement in animal feeds.

4. Corn gluten feed, also used as animal feed.

5. Corn germ meal

6. Corn oil

7. Carbon dioxide (CO2 for soft drinks or dried ice)

8. High fructose corn syrups

After students have written the information in their notebooks, use the Eye Witness News Moment to review the byproducts of ethanol production. Follow these steps to complete the activity:

1. *Establish the two roles each student will play. Explain that when the students are the expert they stand tall and take on the air of an expert, a know-it-all with a pleasant personality. When they are the interviewer students address an imaginary camera, with microphone (pen) in hand, and welcome the viewing audience to "Moments with Dr. (fill in the student's name)." Then they pose questions to the expert about the byproducts of ethanol production story. For example: Facing the camera: Welcome to our show. Today we are interviewing the world-renowned expert in ethanol*

production, Dr. Seth Smith. Turning to the expert: Please tell us, Dr. Seth, what are some by-products from ethanol production? Point the microphone in the direction of the expert. Note: This activity works best when students generate appropriate questions prior to the interview.

2. *Establish the process. Explain that this activity is to aid in the topic. Share that the power lies in how well students can play the roles and use the information they just learned. It is a timed event and they will switch roles midway through the event. Note: The time allocated is dependent upon the amount of content students will be rehearsing. An average time limit is three to five minutes, switching roles midway through.*

3. *Begin Eye Witness News Moment. Have students stand, pair up, and get ready to go "live" at your signal.*

4. *Switch roles. Midway through, get everyone's attention. Students now switch roles. Note: The new expert usually picks up from where the other left off. If the first expert covered all the information, then the new expert simply starts at the beginning.*

5. *Conclude the activity. After everyone has played both roles at least once, students acknowledge each other with "Thank you!" You can now randomly select individuals to explain what their expert said as a way to check for understanding and increasing individual accountability to the content.*



Nice work experts! We really have a solid understanding of the byproducts of ethanol production.

REVIEW/SUMMARY

*To review the concepts of **dry-milling** and **wet-milling**, have students complete the Venn Diagram on AS.C. Have the students label one circle "**dry-milling**" and the other circle "**wet-milling**." A Venn diagram is used to compare and contrast. In the circles, they are to list the individual characteristics of each process and in the portion where they overlap, the similarities.*



To review, let's think compare and contrast the two ***milling*** processes. On the activity sheet you will see a Venn Diagram. We can use this diagram to help us compare and contrast the processes we have been describing. Label one circle ***dry-milling***. *Allow time for students to label one circle.* Label the other circle ***wet-milling***. *Allow time for students to label the other circle*. We will list at least three characteristics specific to the ***dry-milling*** and ***wet-milling*** processes. You are allowed to use any information from today's class. *Give students time to complete this. Be available to assist as needed.*

Notice that there is a portion of the diagram where the two circles overlap. In this area, write down at least three characteristics that the processes have in common. *Again, give students time to complete this and be available for assistance.*

Nice work! Thanks so much for your hard work today. Keep this diagram because it will help us understand the differences between the two processes.

APPLICATION

Extended classroom activity: *Provide students with a blank wet-mill process flowchart. Students are to fill in the blanks for the process based on notes and discussion from class.*

FFA activity: *Students will write a short article that explains the benefits and by-products of ethanol production. The article can be run in the local newspaper promoting biofuels.*

SAE activity: *Have the students outline a potential Agriscience experiment on either the* ***dry-milling*** *or* ***wet-milling*** *process. They will need to be prepared to share this with their classmates.*

EVALUATION

Assess. A

Answers to Assessment:
2 Liquefaction
4 Fermentation
1 Milling
6 Dehydration
3 Saccharification
5 Distillation
7 Denaturing

Short Answer:

1. The major difference in the wet mill and dry mill process is that in the wet mill process After milling, the corn is heated in a solution of water and sulfur dioxide for 24-48 hours to loosen the germ and hull fiber. The germ is then removed from the kernel and corn oil extracted from the germ. The remaining germ meal is added to the hulls and fiber to form corn gluten feed. The only fermentation that occurs in wet-mill processing is that of the germ while the entire seed is used in dry-mill processing.

2. Corn gluten meal, corn gluten feed, also used as animal feed, corn germ meal, corn oil, carbon dioxide, and high fructose corn syrups.

TM.A

II. Wet-milling process has many steps that can make it a costly but beneficial process.

A. Steps in wet-milling process. The wet milling process is a more intensive process than is normally used to produce ethanol, but it produces additional byproducts which can make this a more appealing process. The byproducts come as a result of breaking the corn into its four main components: starch, germ (the heart of a kernel of corn), fiber and protein.

1. First, the cleaned and inspected corn is steeped (soaked) for up to two days, which begins to break down the bonds holding the starch and proteins together.

2. The corn is then coarsely ground up to remove the germ from the rest of the components. The germ can be used to make corn oil, and the remainder of that process creates some feed products which can be given to livestock.

3. The corn, now in the form of slurry, is more finely ground. The fiber is then taken out using an attrition-impact mill. The fiber is used as a major element in animal feeds.

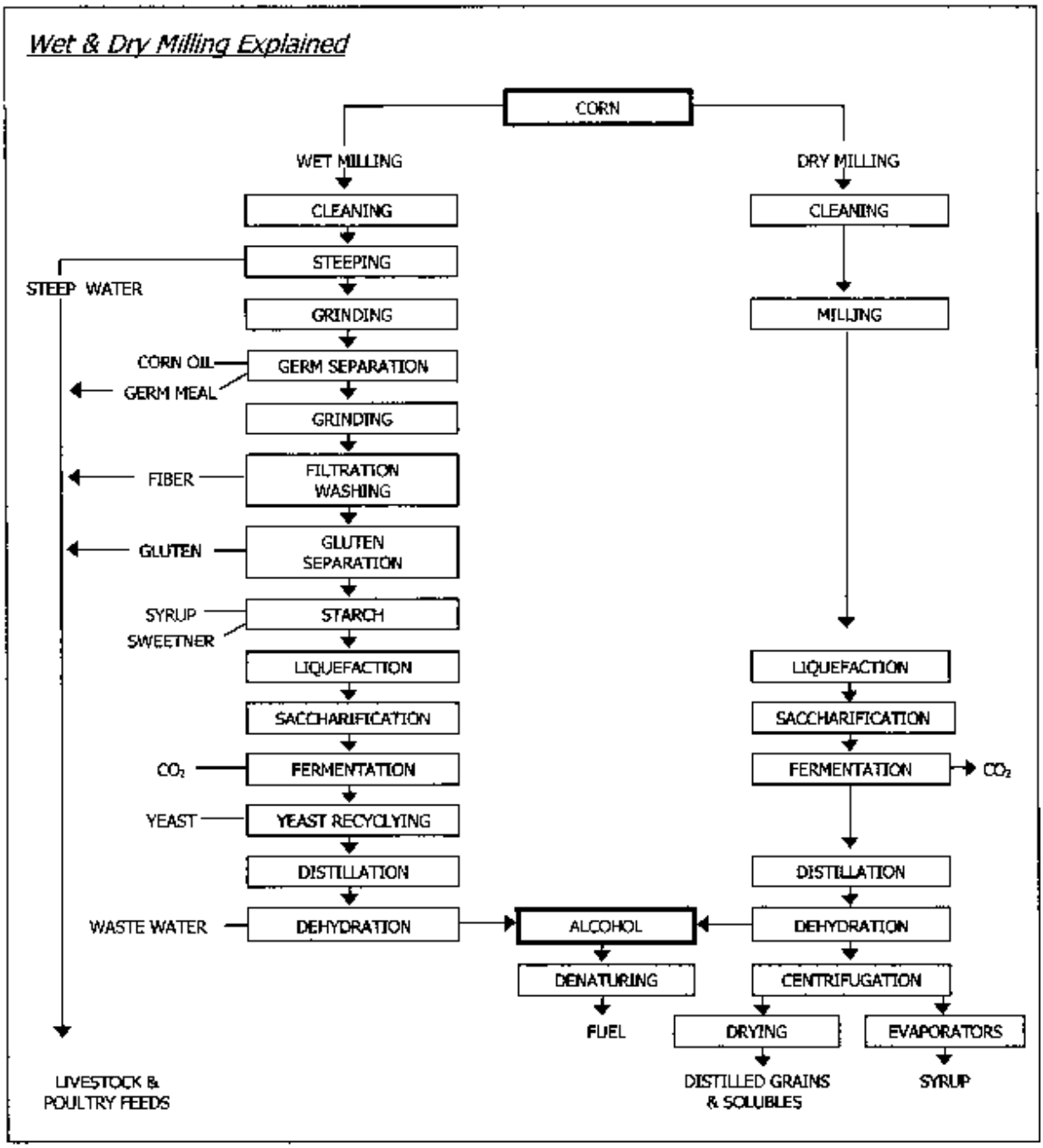
4. The starch and gluten are separated using a centrifuge to make the much denser starch fall to the bottom of the mix. The starch continues in the process towards becoming ethanol, while the gluten is used as another ingredient in animal feeds.

5. Water and enzymes are added that will ferment the starches into ethanol and other alcohols to the remaining starch. In creating the starch mixture, not all the starch can used, so some of the syrup ends up becoming high fructose corn syrup, a common inexpensive sweetener.

6. After fermentation, the alcohol mixture will be nearly ready to be used as an additive, and the CO_2 gas that has collected in the fermentation chamber can be collected and sold to soda companies for carbonation.

B. The advantages of the wet milling process are easy to see with so many byproducts which can be sold to compensate for the cost of the process. However, wet milling is still not a perfect solution. Much of the machinery is more expensive than what is involved in dry milling and the dangerous chemical sulfur dioxide is used, which means additional safety steps much be taken in a wet milling plant.

TM.B


Wet & Dry Milling Explained
CORN
WET MILLING
DRY MILLING
CLEANING
CLEANING
STEEPING
STEEP WATER
GRINDING
MILLING
CORN OIL
GERM SEPARATION
GERM MEAL
GRINDING
FIBER
FILTRATION WASHING
GLUTEN
GLUTEN SEPARATION
SYRUP
STARCH
SWEETNER
LIQUEFACTION
LIQUEFACTION
SACCHARIFICATION
SACCHARIFICATION
CO_2
FERMENTATION
FERMENTATION
CO_2
YEAST
YEAST RECYCLYING
DISTILLATION
DISTILLATION
WASTE WATER
DEHYDRATION
ALCOHOL
DEHYDRATION
DENATURING
CENTRIFUGATION
FUEL
DRYING
EVAPORATORS
LIVESTOCK & POULTRY FEEDS
DISTILLED GRAINS & SOLUBLES
SYRUP

TM.C

I. There are several byproducts from ethanol production.

A. Each bushel of corn (56lbs.) can produce up to 2.5 gallons of ethanol fuel

1. Only the starch from corn is used to make ethanol.

B. Most of the substance of the corn kernel remains, leaving the protein and valuable co-products to be used in the production of food for people, livestock, feed and various chemicals.

1. Animal Feed: Feed grain for animals is produced from the residue left over after the production of the alcohol.

2. Corn syrup: An expanding market and the high cost of fructose corn syrup encouraged expansion of wet mill plants that produce the syrup as a by-product of the ethanol production process.

3. Corn gluten meal, which can be used as a natural herbicide or as a high protein supplement in animal feeds.

4. Corn gluten feed, also used as animal feed.

5. Corn germ meal

6. Corn oil

7. Carbon dioxide (CO_2 for soft drinks or dried ice)

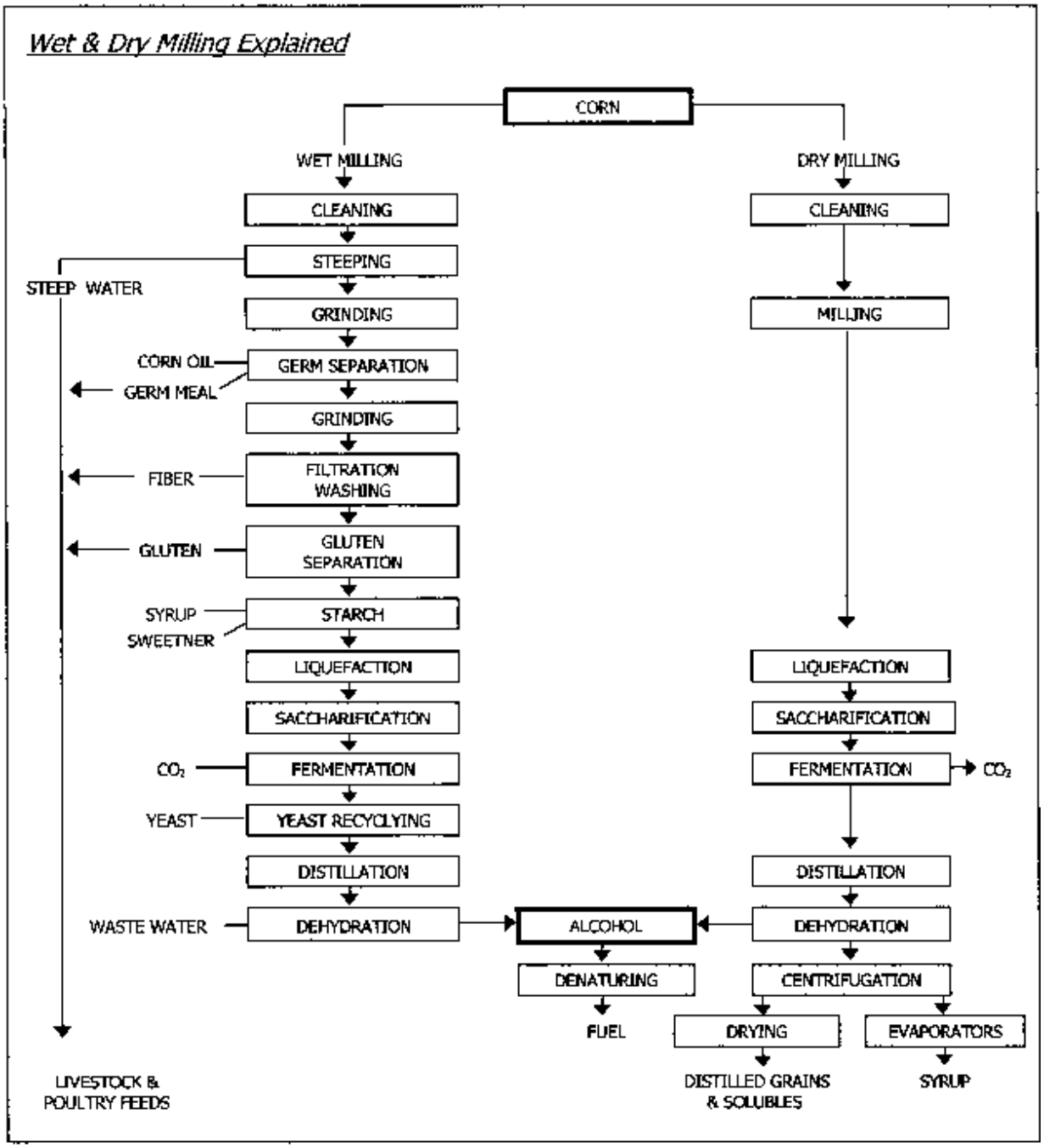
8. High fructose corn syrups

AS.A

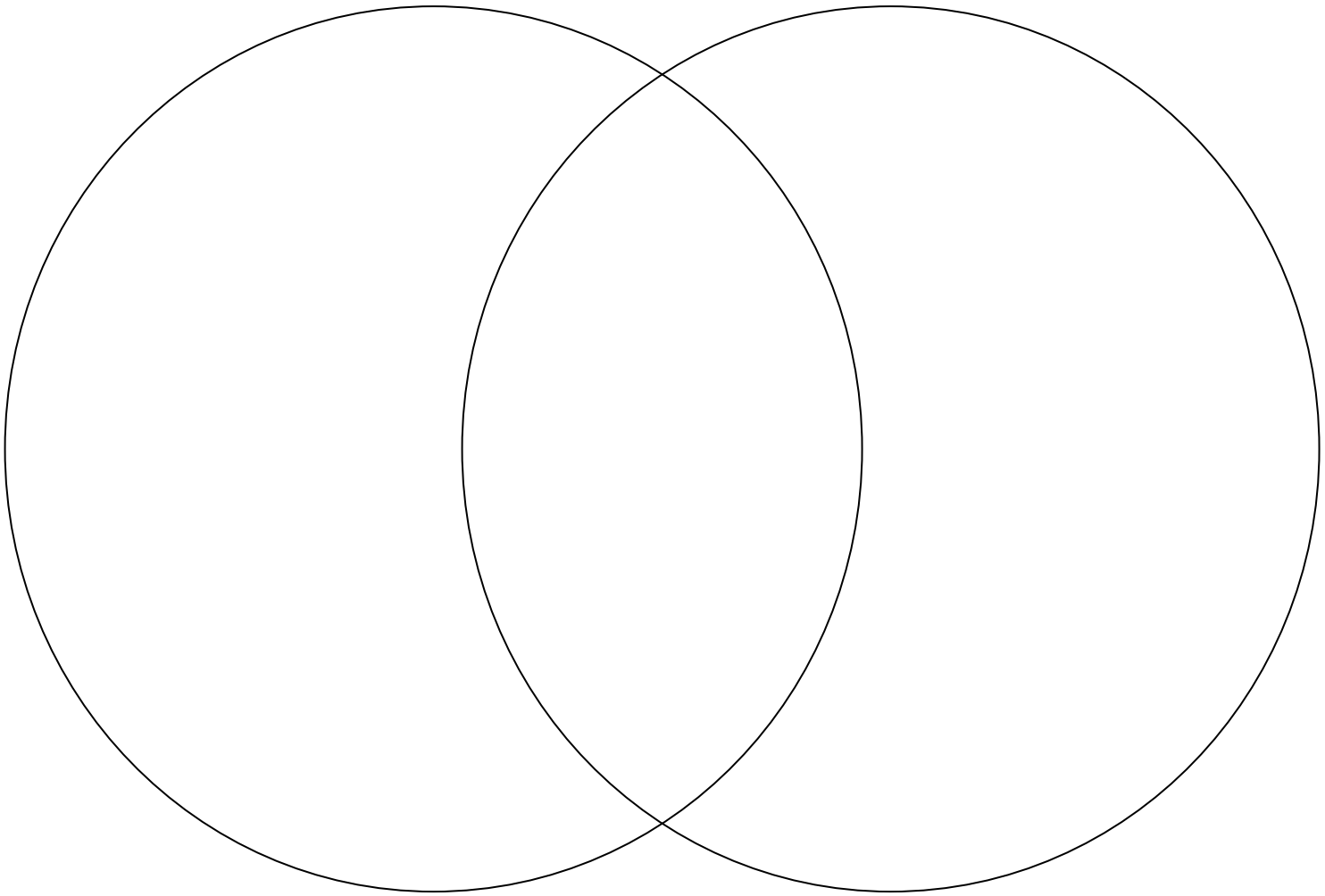
Step	Description	Icon
A. Milling:	After the corn, barley, or wheat is cleaned, it will pass first through hammer mills which grind it into fine powder.	
B. Liquefaction:	The meal will then be mixed with water and an enzyme (alpha-amylase), and will pass through cookers where the starch is liquefied. A pH of 7 is maintained by adding sulfuric acid or sodium hydroxide. Heat is applied to enable liquefaction. Cookers with a high temperature stage 120-150 degrees Celsius and lower holding period of 95C will be used. The higher temperature reduces the bacteria in the mash.	
C. Saccharification:	The mash from the cookers will be cooled and the enzyme gluco-amylase will be added to convert starch molecules to fermentable sugars (dextrose).	
D. Fermentation:	Yeast will be added to the mash to ferment the sugars to Ethanol and carbon dioxide. Using a continuous process, the fermenting mash will flow or cascade, through several fermenters until the mash is fully fermented	

	and leaves the tank. In a batch fermentation process, the mash stays in one fermenter for about 48 hours.	
E. Distillation:	The fermented mash will then be pumped to the continuous flow, multi-column distillation system where the 10% alcohol will be removed from the solids and water. The alcohol will leave the top of the final column at about 96% strength, and the residue mash, called stillage, will be transferred from the base of the column to the co-product processing area.	
F. Dehydration:	The alcohol will then pass through the dehydration system where the remaining water will be removed. Most plants use a molecular sieve to capture the last bit of water in the ethanol. The alcohol at this stage is call anhydrous.	
G. Denaturing:	Ethanol that will be used for fuel is then denatured with a small amount of some product like gasoline, to make it unfit for human consumption.	

AS.B


Wet & Dry Milling Explained
CORN
WET MILLING
DRY MILLING
CLEANING
CLEANING
STEEPING
STEEP WATER
GRINDING
MILLING
CORN OIL
GERM SEPARATION
GERM MEAL
GRINDING
FIBER
FILTRATION WASHING
GLUTEN
GLUTEN SEPARATION
SYRUP
SWEETNER
STARCH
LIQUEFACTION
LIQUEFACTION
SACCHARIFICATION
SACCHARIFICATION
CO_2
FERMENTATION
FERMENTATION
CO_2
YEAST
YEAST RECYCLYING
DISTILLATION
DISTILLATION
WASTE WATER
DEHYDRATION
ALCOHOL
DEHYDRATION
DENATURING
CENTRIFUGATION
FUEL
DRYING
EVAPORATORS
LIVESTOCK & POULTRY FEEDS
DISTILLED GRAINS & SOLUBLES
SYRUP

AS.C



Assess.A

Sequence:
Indicate the major steps used in a **dry milling process** by placing a number in the blank provided to indicate the proper steps in order.

_____ Liquefaction
_____ Fermentation
_____ Milling
_____ Dehydration
_____ Saccharification
_____ Distillation
_____ Denaturing

Short Answer:

1. Explain the major difference in the dry and wet-milling process?

2. Identify three byproducts of Ethanol production?