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Precision Fermentation: Estimation of Fermentable Sugars, and Optimization of Baker's Yeast Production Using Brix Measurements in Second Boil Out Molasses

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Total Solids (TS), Predictability, Cost-Efficiency, Second Boil Out (BBO) molasses, Fermentation.

ABSTRACT:
Second Boil Out (BBO) molasses, a by-product of sugar refining, is a commonly used feedstock for industrial fermentation processes, including the production of baker's yeast. Efficient yeast production is dependent on the concentration of fermentable sugars—primarily sucrose, glucose, and fructose—within the molasses. This study presents a method for estimating fermentable sugar content in BBO molasses based on Total Solids (TS) measurements, using Brix values obtained via refractometry. A mathematical model is introduced to relate Brix readings to fermentable sugar concentrations, enabling producers to quickly assess molasses quality and optimize fermentation performance. The method is particularly valuable for improving yield predictability and cost-efficiency in baker's yeast manufacturing.

1. Introduction:

Baker's yeast production relies on fermentation processes that require a consistent and readily available source of fermentable sugars. Molasses, particularly from the Second Boil Out (BBO) stage of sugar refining, is a cost-effective substrate due to its high sugar concentration and broad availability (Panda & Naidu, 2000; Eggleston, 2002). However, BBO molasses also contains a significant amount of non-fermentable solids, such as minerals and organic acids, which can negatively affect fermentation efficiency (Narendranath & Power, 2005; Smith & Hardy, 2001).

A key challenge in utilizing BBO molasses lies in accurately estimating its fermentable sugar content. Conventional laboratory analyses—such as DNS assays or chromatography—are time-consuming and may not be suitable for real-time quality control (Miller, 1959). Brix, a widely used measure of total soluble solids, offers a practical alternative. When measured with a refractometer, Brix values can be used to estimate total sugar and, by extension, fermentable sugar concentrations (Brix, 1988; Gawel et al., 2007). This paper proposes and validates a method for such estimation, offering a rapid, cost-effective tool for optimizing fermentation in baker's yeast production.

2. Molasses Composition and Fermentable Sugars:

BBO molasses is a complex mixture of sugars, non-sugar solids, and moisture. Its composition varies depending on the raw material and processing conditions (Eggleston, 2002; Czarnik & Russo, 2000). A typical compositional breakdown is provided in Table 1.

Table 1: Approximate Composition of BBO Molasses

Component	Percentage Composition
Total Sugars	45% - 55%
Sucrose (Primary Sugar)	30% - 40%
Glucose	5% - 10%
Fructose	5% - 8%
Non-Sugar Solids (Ash)	15% - 25%
Water	20% - 30%
Organic Acids (e.g., Acetic Acid)	2% - 3%
Minerals (e.g., Potassium, Calcium)	5% - 7%
Other Organic Compounds (Proteins, etc.)	5% - 10%

2.1 Fermentable Sugars:

Sucrose is the predominant sugar and is efficiently metabolized by *Saccharomyces cerevisiae* during alcoholic fermentation (Kirsop & Hunter, 1990). Glucose and fructose are present due to the hydrolysis of sucrose during the boiling process and are also readily fermentable by yeast (Zhang & Greasham, 1999).

2.2 Non-Fermentable Solids:

Ash, minerals, organic acids, and other compounds are non-fermentable but may impact fermentation performance by affecting osmotic pressure, pH, and nutrient balance (Narendranath & Power, 2005). High levels of non-sugar solids may inhibit yeast growth and lower overall yields (Smith & Hardy, 2001; Panda & Naidu, 2000).

Key Components:

2.2.1 Total Sugars (45% - 55%):

The total soluble sugars in molasses, including sucrose, glucose, and fructose, contribute to approximately 45% to 55% of the molasses content. These sugars are the primary source of fermentable material during yeast fermentation.

2.2.2 Sucrose (30% - 40%):

Sucrose is the dominant sugar in molasses, accounting for 30% to 40% of the total composition. As the primary fermentable sugar, sucrose is efficiently converted by yeast into ethanol and carbon dioxide during fermentation.

2.2.3 Glucose and Fructose (10% - 18% of total sugars):

Glucose and fructose are invert sugars formed through the hydrolysis of sucrose during the boiling process. These sugars, which make up 5% to 10% of the total molasses content, are also fermentable by yeast and contribute to the overall fermentation process.

2.2.4 Non-Sugar Solids (15% - 25%):

The non-sugar solids in molasses include minerals (e.g., potassium, calcium), proteins, and other organic compounds. These non-fermentable solids reduce the overall fermentable sugar content available to yeast, which can hinder fermentation efficiency. The higher the proportion of non-sugar solids, the less efficient the fermentation process becomes. These non-sugar solids may need to be removed or accounted for to optimize fermentation yields.

2.2.5 Water (20% - 30%):

Water is a significant component in molasses, helping to dissolve the sugars and other compounds, but it does not contribute to fermentation directly.

2.2.6 Organic Acids (2% - 3%):

Organic acids, such as acetic acid, are present in molasses and may influence fermentation by affecting the pH of the solution. Their presence in higher concentrations could inhibit yeast activity if not carefully controlled.

2.2.7 Minerals and Other Organic Compounds (5% - 10%):

These include various essential minerals and proteins, which are non-fermentable but may be beneficial to yeast health in small quantities. However, excessive minerals or organic compounds can reduce fermentation efficiency.

2.3 Fermentation Implications:

For fermentation applications, such as baker's yeast production, the primary focus is on the fermentable sugars (sucrose, glucose, and fructose). The non-fermentable solids, including ash, minerals, organic acids, and other organic compounds, reduce the available sugar content and can hinder the fermentation process by making it less efficient.

Molasses with higher total sugar content and lower non-sugar solids is preferable for fermentation, as it provides more available fermentable material for yeast growth and ethanol production. For efficient fermentation, it

may be necessary to treat or dilute molasses to remove or minimize the impact of non-fermentable solids.

BBO molasses is a valuable resource for yeast fermentation, particularly in applications such as baker's yeast production, due to its rich content of sucrose and invert sugars like glucose and fructose. However, the presence of non-fermentable solids, such as ash and organic acids, must be managed to ensure optimal fermentation efficiency. The composition of molasses varies, but its suitability for fermentation largely depends on maximizing the fermentable sugar content and minimizing the non-fermentable solids.

3. Relationship between Brix and Fermentable Sugars

Brix represents the percentage of total soluble solids in a liquid and is frequently used as a proxy for Total Solids (TS) in molasses (Brix, 1988). However, because Brix includes both fermentable and non-fermentable components, a correction factor is necessary to estimate the actual fermentable sugar content.

Based on empirical analysis and previous work on sugar composition in fermentation substrates (Czarnik & Russo, 2000), the following relationships were established:

- Total Sugars ≈ 62.5% of Brix
- Fermentable Sugars ≈ 92.5% of Total Sugars

This leads to the derived formula:

Fermentable Sugars (%) = Brix Value×0.625×0.925

Where:

- 0.625 reflects the average proportion of total sugars within Brix,
- 0.925 represents the proportion of total sugars that are fermentable (Zhang & Greasham, 1999).

4. Methodology for Calculating Fermentable Sugars:

Using the above formula, fermentable sugar content was calculated for Brix values ranging from 70% to 80%, which is typical for BBO molasses (Eggleston, 2002).

Table 2: Estimated Fermentable Sugars from Brix Values

Brix (°Bx)	Total Sugars (% of Brix)	Fermentable Sugars (% of Brix)	Fermentable Sugars (%)
70%	70% × 0.625 = 43.75%	43.75% × 0.925 = 40.39%	40.4%
71%	71% × 0.625 = 44.375%	44.375% × 0.925 = 40.99%	41.0%
72%	72% × 0.625 = 45%	45% × 0.925 = 41.625%	41.6%
73%	73% × 0.625 = 45.625%	45.625% × 0.925 = 42.14%	42.1%
74%	74% × 0.625 = 46.25%	46.25% × 0.925 = 42.81%	42.8%
75%	75% × 0.625 = 46.875%	46.875% × 0.925 = 43.34%	43.3%
76%	76% × 0.625 = 47.5%	47.5% × 0.925 = 43.94%	43.9%
77%	77% × 0.625 = 48.125%	48.125% × 0.925 = 44.51%	44.5%
78%	78% × 0.625 = 48.75%	48.75% × 0.925 = 45.06%	45.1%
79%	79% × 0.625 = 49.375%	49.375% × 0.925 = 45.68%	45.7%
80%	80% × 0.625 = 50%	50% × 0.925 = 46.25%	46.3%

This table allows baker's yeast producers to quickly determine the fermentable sugar content in BBO molasses based on Brix measurements, facilitating the selection of molasses with optimal sugar concentrations for fermentation.

5. Application in Baker's Yeast Manufacturing:

Baker's yeast, mostly made up of Saccharomyces cerevisiae, is a key ingredient in the food industry due to its ability to ferment sugars to produce carbon dioxide, which helps bread rise. A variety of biotechnological and industrial techniques are used to produce baker's yeast, with the goal of optimizing production, purity, and yeast cell activity.

5.1 Real-Time Quality Control:

Using a refractometer, producers can quickly assess the sugar content in molasses batches (Gawel et al., 2007), facilitating immediate acceptance or rejection based on fermentation suitability.

5.2 Cost Optimization:

By selecting molasses with high fermentable sugar content, the need for supplementary sugar additions is reduced, improving cost-efficiency in the manufacturing process (Zhang & Greasham, 1999).

5.3 Enhanced Fermentation Efficiency:

Precise knowledge of fermentable sugar levels supports better control of fermentation conditions such as pH, temperature, and nutrient dosing (Narendranath & Power, 2005; Panda & Naidu, 2000), resulting in improved yeast yield and process consistency.

6. Conclusion:

This study presents a practical and effective method for estimating fermentable sugar content in BBO molasses using refractometric Brix measurements. The proposed model enables yeast manufacturers to quickly evaluate molasses quality, ensuring consistency and efficiency in fermentation processes. Adoption of this technique can contribute to more sustainable, cost-effective, and predictable baker's yeast production operations.

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