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Thermostable Alpha Amylase Enzyme for Industrial Ethanol Production

Enzymes.bio Research Team · Wellington, New Zealand · June 16, 2026

Thermostable alpha amylase is a heat-tolerant starch-liquefying enzyme used in ethanol production to convert thick, cooked starch slurry into shorter dextrins and maltooligosaccharides. By randomly cleaving internal α-1,4 glycosidic bonds in amylose and amylopectin, it lowers mash viscosity and prepares starch-rich feedstocks for saccharification into fermentable sugars.

Enzymes.bio supplies Thermostable Alpha Amylase Enzyme for Industrial Ethanol Production as a 1 kg product available for direct online purchase. After online payment, the order is processed and shipped, and a Certificate of Analysis and Safety Data Sheet are provided with the order.

Industrial role in starch-based ethanol production

In starch-based ethanol production, the first major conversion problem is physical as much as biochemical: starch-rich mash becomes viscous when heated with water. Corn, cassava, wheat, sorghum, rice, sago, tapioca residues, and many food-waste streams contain starch that must be opened, liquefied, and converted into fermentable sugars before microorganisms can efficiently produce ethanol. Thermostable alpha amylase is used at the front end of this pathway because it can act during hot starch processing, when swollen or gelatinized starch is accessible but the mash is still demanding for less heat-stable enzymes [1].

Alpha-amylase is an endo-acting starch hydrolase. “Endo-acting” means it attacks bonds inside the starch chain rather than trimming only from the chain ends. The enzyme hydrolyzes internal α-1,4 linkages in amylose and amylopectin, shortening long glucose polymers into soluble dextrins and maltooligosaccharides. This is why alpha amylase is described as a liquefaction enzyme: it rapidly reduces polymer size and viscosity, but it is not normally the enzyme that completes conversion all the way to glucose [1].

In an ethanol plant or pilot ethanol process, this liquefaction step supports the later saccharification and fermentation stages. After alpha amylase has shortened the starch chains, glucoamylase or related saccharifying enzymes can release glucose more effectively from the dextrin mixture. Yeast or another ethanol-producing organism then ferments those sugars into ethanol and carbon dioxide. Studies on cassava starch, red sorghum starch, sago starch, rice, and tapioca solid waste all reflect this same general logic: starch-rich material is hydrolyzed enzymatically so that fermentable sugars become available for ethanol production [2].

What changes in the mash when alpha amylase is added

Starch granules are semi-crystalline particles made mainly of two glucose polymers. Amylose is mostly linear, while amylopectin is highly branched, with α-1,4 chains connected by α-1,6 branch points. During heating in water, granules swell, crystalline regions loosen, and amylose can leach into the liquid phase. The result is a thick paste in which long hydrated chains trap water and resist flow. This is the practical reason starch liquefaction matters: without chain scission, the slurry can be difficult to pump, mix, heat uniformly, or expose evenly to downstream enzymes.

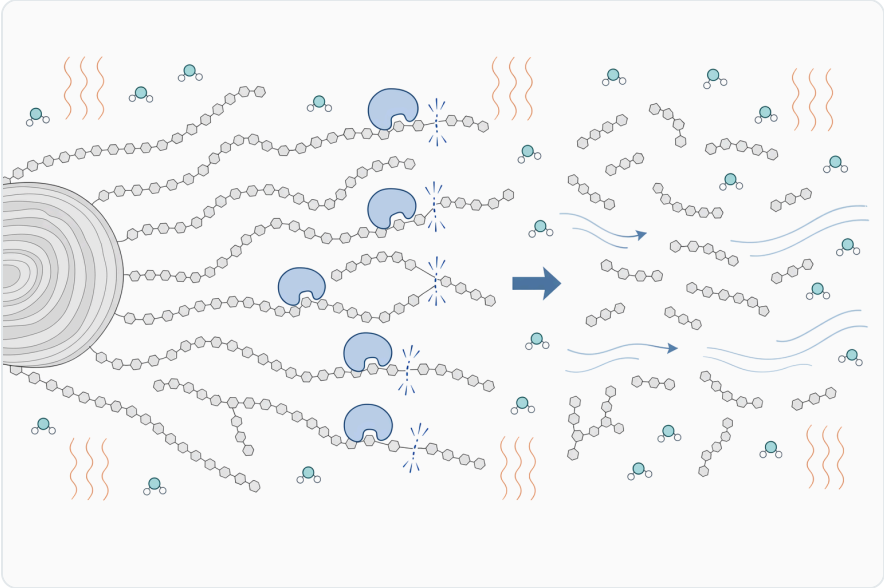

Figure 1. Thermostable alpha amylase liquefies starch by cleaving internal α-1,4 glycosidic bonds in amylose and amylopectin to form dextrins and maltooligosaccharides.

Thermostable alpha amylase changes that physical state by cutting long α-1,4 chains into shorter segments. A long amylose molecule that contributes strongly to viscosity becomes many smaller dextrins; amylopectin branches remain, but the outer and internal α-1,4 segments are shortened. The

mash becomes less elastic and less stringy because shorter chains entangle less and hold water differently. At the same time, the enzyme creates many new chain ends and smaller soluble fragments, giving saccharifying enzymes more access points in the next stage.

The enzyme does not generally remove α-1,6 branch points by itself. That means alpha amylase liquefaction produces a mixture: maltodextrins, maltose, maltotriose, other maltooligosaccharides, and branched limit dextrins. For ethanol production, this is useful but incomplete. Liquefaction turns an unmanageable starch paste into a more processable carbohydrate stream; saccharification then pushes the dextrin mixture toward glucose and other fermentable sugars.

Why thermostability matters during liquefaction

The “thermostable” part of thermostable alpha amylase is central to its industrial value. Starch becomes much more enzyme-accessible after heat treatment, because granule swelling and gelatinization expose glucan chains that are partly protected in native granules. If the enzyme loses structure under those hot processing conditions, its active site can no longer bind and cleave starch effectively. A thermostable enzyme retains functional shape longer under heat, allowing liquefaction to occur when the substrate is most accessible [3].

Thermostability also supports process practicality. Hot liquefaction helps reduce mash viscosity early, before the material has moved into downstream saccharification and fermentation. It can also fit process environments where heat treatment is already used for starch cooking and for reducing the microbial load of the slurry. The enzyme is not a sanitation system, but a heat-tolerant liquefaction enzyme is compatible with hot processing conditions that are less favorable to many unwanted organisms [1].

Many industrially relevant alpha-amylases are microbial, especially bacterial enzymes from thermotolerant or thermophilic organisms. Research continues to describe thermostable amylases from diverse microbial sources, including thermophilic Bacillus strains and other organisms, because heat-stable starch hydrolysis remains important in food, starch, brewing, textile, detergent, and biofuel applications [4]. This broad enzyme class is well established even though individual enzyme preparations can differ in substrate behavior and operating tolerance.

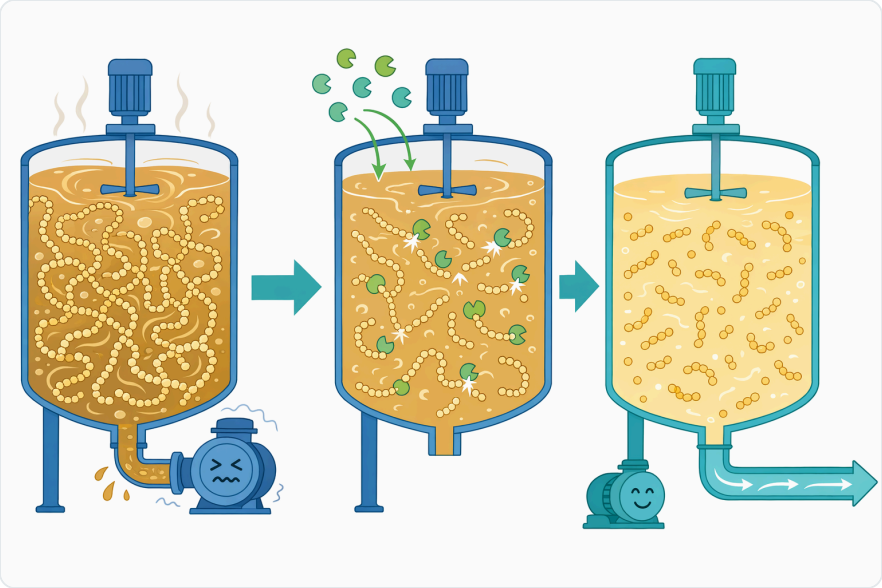

Figure 2. Cutting long hydrated starch chains into shorter fragments lowers mash viscosity and improves processability.

Calcium interaction is one reason alpha-amylase stability varies across enzyme sources. Many alpha-amylases use bound metal ions to help maintain protein structure, but calcium-independent alpha-amylases have also been reported. For example, a characterized alpha-amylase from *Talaromyces pinophilus* was described as calcium-independent, illustrating that the enzyme family contains more than one structural strategy for maintaining catalytic function [5]. For users, the important point is not the structural detail itself, but what it explains: heat tolerance and stability arise from the enzyme's folded protein architecture, not from a generic "chemical" effect.

Liquefaction, saccharification, and fermentation as separate process jobs

Thermostable alpha amylase performs one essential job in ethanol production, but it does not perform every job. A practical way to understand the ethanol pathway is to separate the stages by what physically and chemically changes in the feedstock.

Process stage	Main transformation	Typical enzyme or biological role	Why it matters for ethanol
Starch cooking / gelatinization	Starch granules swell and become more accessible; viscosity rises sharply	Heat and water open the starch structure	Makes starch chains available but creates a thick mash
Liquefaction	Long α-1,4 starch chains are cut into shorter dextrins	Thermostable alpha amylase	Reduces viscosity and creates soluble dextrin fragments

Process stage	Main transformation	Typical enzyme or biological role	Why it matters for ethanol
Saccharification	Dextrins are further converted toward glucose and other fermentable sugars	Glucoamylase and related enzymes	Produces sugars that yeast or other microbes can ferment
Fermentation	Sugars are converted to ethanol and carbon dioxide	Yeast or another ethanol-producing organism	Generates the target ethanol product
Integrated or simultaneous approaches	Hydrolysis and fermentation are partly combined	Enzymes and microbes operate in one coordinated process	Can reduce process steps when feedstock and organisms are suitable

This division of labor is visible in studies of starch-based ethanol processes. Cassava starch has been converted by enzymatic hydrolysis followed by fermentation, with additional process integration such as ex-situ nanofiltration studied for ethanol recovery and process performance [6]. Rice has also been investigated in an enzymatic process designed for simultaneous production of trehalose, bioethanol, and a high-protein product, showing how starch conversion can be integrated with broader bioprocess objectives [7].

Single-step and simultaneous routes are also actively studied. One cassava study examined ethanol production from raw cassava starch using a combination of raw starch hydrolysis and fermentation, and importantly reported scale-up from 5 L laboratory work to a 200 L pilot plant and then to 3000 L industrial fermenters [8]. That study is relevant because it shows that starch hydrolysis and fermentation can be integrated at meaningful scale, although raw-starch processes and hot liquefaction processes are not identical.

Feedstocks where thermostable alpha amylase is relevant

Thermostable alpha amylase is most directly relevant when the ethanol feedstock contains starch. Common examples include cereal grains, tubers, root crops, and starch-containing residues. Cassava is a frequent research feedstock because it contains abundant starch and is widely used in ethanol and industrial carbohydrate processing. Studies have examined cassava starch hydrolysis and fermentation, including process combinations that improve conversion and recovery [6].

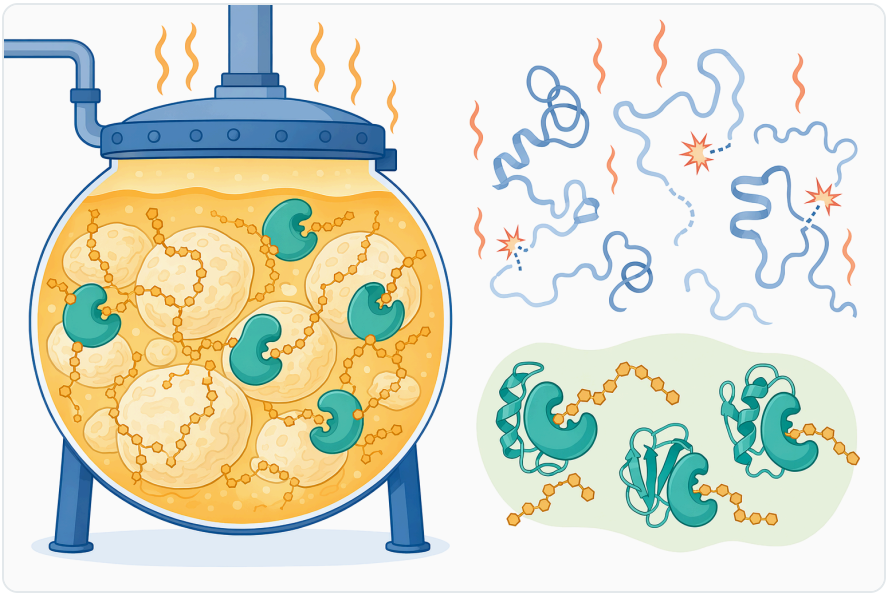

Figure 3. Thermostability allows alpha amylase to retain catalytic structure during hot starch liquefaction when gelatinized starch is most accessible.

Sorghum is another starch crop where enzymatic hydrolysis is important. Work on red sorghum starch has studied how substrate and enzyme concentration affect glucose syrup production by enzymatic hydrolysis, reflecting a central point for ethanol processes: the usable sugar pool depends on how effectively starch is hydrolyzed before fermentation [2]. While glucose syrup production is not identical to fuel ethanol production, the carbohydrate conversion step is closely related.

Sago starch has been investigated using both enzymatic and acid hydrolysis for ethanol preparation. That comparison matters because it highlights the practical difference between controlled enzymatic hydrolysis and harsher chemical hydrolysis. Enzymes act selectively on glycosidic bonds under milder process conditions, while acid hydrolysis can be less selective and may create degradation products depending on conditions [9].

Tapioca solid waste, also known as onggok, is another starch-rich residue studied for bioethanol production in batch reactors. This type of work is important because ethanol feedstocks are not limited to refined grain starch; residues from starch processing can still contain carbohydrates that require hydrolysis before fermentation [10].

Food waste can also contain a significant starch fraction, especially when bakery, rice, noodle, potato, or mixed prepared-food residues are present. Waste pizza, for example, has been studied for ethanol production by enzymatic hydrolysis and fermentation, showing that starch-rich prepared-food waste can be treated as a carbohydrate source rather than only as disposal material [11]. A separate process-design and techno-economic study on fuel ethanol from food waste also used enzymatic hydrolysis and fermentation as the core conversion route [12].

Substrate structure affects enzyme access

Not all starch behaves the same during hydrolysis. Granule size, botanical origin, crystallinity, amylose-to-amylopectin ratio, and prior milling or heat treatment all influence how rapidly enzymes can reach α-1,4 bonds. Barley research has shown that small and large starch granules have different gelatinization characteristics and that these differences affect enzymatic hydrolysis and sugar production during mashing [13].

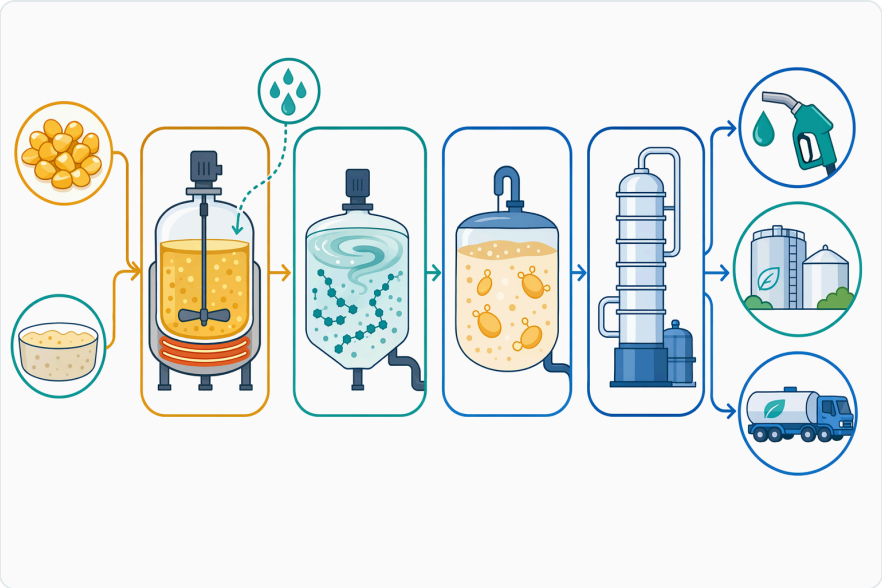

Figure 4. Starch ethanol production separates cooking, alpha-amylase liquefaction, saccharification, fermentation, and ethanol recovery into distinct process jobs.

This matters because alpha amylase does not hydrolyze starch by magic contact with a powder surface. The enzyme must physically bind to accessible glucan regions and position the α-1,4 bond in its active site. Dense, intact, or less-gelatinized granules expose fewer attack points, while cooked or disrupted starch exposes more chain segments. Milling can also increase surface area and improve enzyme access; work on starch-rich *Chlorella sorokiniana* biomass examined how milling and enzymatic hydrolysis affected glucose production, illustrating the importance of physical accessibility even when starch is present [14].

Raw-starch-digesting alpha-amylases are a specialized area because they can attack granular starch more directly. A moderately thermostable raw-starch-digesting alpha-amylase from endophytic *Streptomyces mobaraensis* has been described, showing that some enzymes combine heat tolerance with the ability to digest less-processed starch [15]. However, raw-starch capability is enzyme-specific; the general industrial role of thermostable alpha amylase remains liquefaction of heated, accessible starch.

Starch ethanol versus cellulosic ethanol

Thermostable alpha amylase is a starch-processing enzyme. It is not the main enzyme for cellulose, hemicellulose, or lignin-rich biomass. This distinction is important because many ethanol feedstocks are mixtures. Corn grain, cassava, rice, sorghum, and food waste may contain starch that alpha amylase can liquefy, while corn stover, sugarcane bagasse, oil palm trunk, and other lignocellulosic materials require pretreatment and cellulolytic or hemicellulolytic enzymes to release fermentable sugars.

Research on corn stover emphasizes pretreatment strategies to improve enzymatic hydrolysis and cellulosic ethanol production, reflecting the fact that lignocellulose must first be opened structurally before enzymes can access cellulose and hemicellulose [16]. Similarly, sugarcane bagasse studies have used low-temperature aqueous ammonia pretreatment, two-stage high-solids enzymatic hydrolysis, and fermentation organisms such as *Candida tropicalis* for co-production of ethanol and xylitol [17].

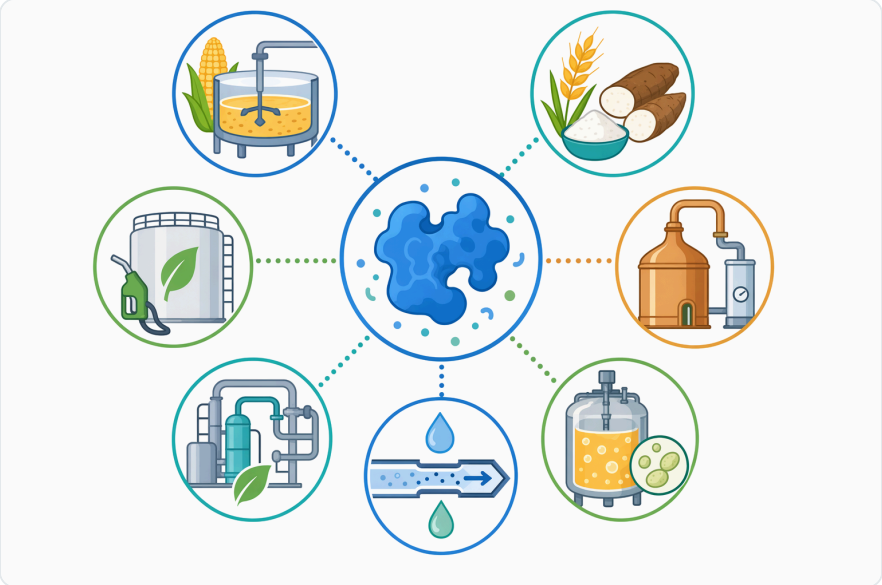

Figure 5. Thermostable alpha amylase is relevant to starch-rich ethanol feedstocks including corn, cassava, sorghum, rice, sago, tapioca residues, and food waste.

Other non-starch or mixed biomasses follow the same principle. Dried oil palm trunk has been treated by hydrothermolysis followed by enzymatic hydrolysis for ethanol production, while *Chlorella* biomass has been studied using hydrothermal pretreatment and enzymatic hydrolysis to improve bioethanol production [18]. These studies are valuable for ethanol technology broadly, but alpha amylase is most relevant when the carbohydrate needing conversion is starch or starch-derived dextrin.

Enzyme hydrolysis compared with acid hydrolysis

Both enzymatic hydrolysis and acid hydrolysis can break carbohydrate polymers, but they do so in different ways. For starch ethanol production, thermostable alpha amylase offers bond-specific liquefaction: it targets α-1,4 linkages in starch and produces dextrins under process conditions compatible with downstream biological conversion. Acid hydrolysis is chemical and less enzyme-specific; it can hydrolyze starch but may require harsher conditions and careful control to avoid sugar degradation.

Approach	How starch is broken	Main practical effect	Relevance to ethanol
Thermostable alpha amylase liquefaction	Enzyme selectively cleaves internal α-1,4 bonds in amylose and amylopectin	Rapid viscosity reduction and dextrin formation	Prepares starch mash for saccharification and fermentation
Saccharifying enzyme treatment	Enzymes release glucose and smaller fermentable sugars from dextrins	Increases fermentable sugar concentration	Feeds yeast or other ethanol-producing microbes
Acid hydrolysis	Acid chemically hydrolyzes glycosidic bonds	Can release sugars but is less biologically selective	Used in some studies, but process severity and byproducts must be managed
Combined process design	Hydrolysis and fermentation are arranged sequentially or simultaneously	Balances sugar release with ethanol formation	Common in starch and waste-to-ethanol research

The sago starch study that compared enzymatic and acid hydrolysis for ethanol preparation is a useful example because it frames both routes as possible starch-conversion methods while making the enzymatic route directly relevant to fermentation-based ethanol [9]. For industrial users, the value of alpha amylase lies in controlled liquefaction that fits biological downstream processing.

Evidence from ethanol and starch-conversion studies

The strongest evidence for thermostable alpha amylase in ethanol production comes from the established industrial role of alpha-amylase in starch liquefaction and from the large body of research using enzymatic hydrolysis as a gateway to ethanol fermentation. Microbial alpha-amylase reviews describe continuing progress, challenges, and industrial perspectives for this enzyme class, including its importance across starch-processing and biotechnological sectors [1].

Cassava provides a clear starch-to-ethanol example. In one study, ethanol production from raw cassava starch was developed as a single-step process combining raw starch hydrolysis and fermentation, then scaled from 5 L laboratory scale to 200 L pilot scale and 3000 L industrial fermenters [8]. The scale-up numbers are especially useful because they show that starch hydrolysis plus fermentation is not only a bench concept; it can be evaluated across progressively larger production volumes.

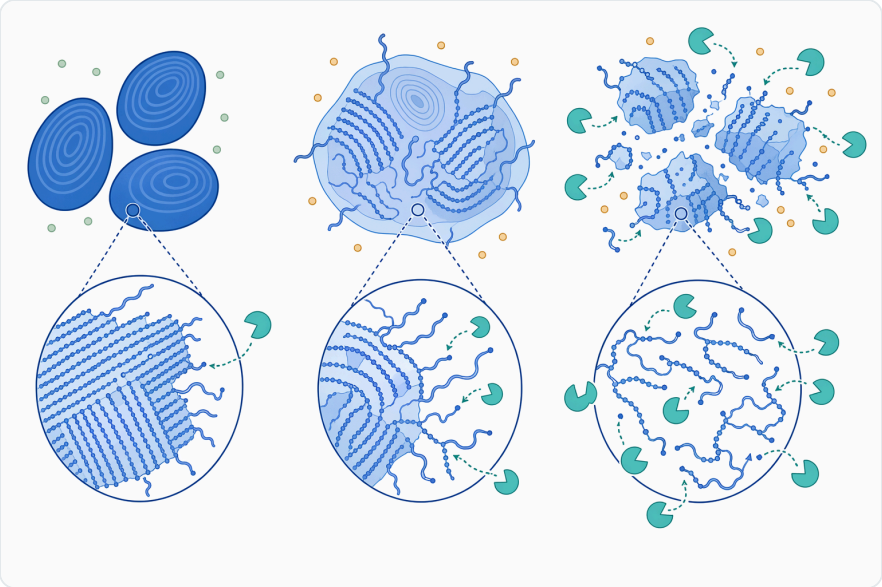

Figure 6. Granule structure, gelatinization, and physical disruption affect how readily alpha amylase can reach starch α-1,4 bonds.

Other starch feedstocks support the same process logic. Red sorghum starch hydrolysis has been studied for glucose syrup production, sago starch has been hydrolyzed for ethanol preparation, cassava starch has been converted by enzymatic hydrolysis and fermentation, and tapioca solid waste has been processed for bioethanol in a batch reactor [10]. These are different materials and process designs, but they all depend on making starch-derived sugars available.

Prepared food waste extends the relevance beyond agricultural crops. Waste pizza has been converted to ethanol through enzymatic hydrolysis and fermentation, while a broader fuel-ethanol process design from food waste also used enzymatic hydrolysis and fermentation as the conversion foundation [12]. In these streams, thermostable alpha amylase is relevant when starch-rich fractions contribute significantly to the carbohydrate load.

Practical benefits stated realistically

The most immediate benefit of thermostable alpha amylase is viscosity reduction. When long starch chains are cut into shorter dextrins, the mash becomes less resistant to flow. This can improve mixing, heat distribution, and enzyme contact. The benefit is especially important in high-solids starch

processing, where viscosity can otherwise become a limiting physical constraint.

A second benefit is improved downstream sugar release. Alpha-amylase hydrolysis opens the starch structure and creates a dextrin pool that saccharifying enzymes can attack more effectively. Because glucoamylase and related enzymes work from chain ends, the creation of more shorter chains can improve access to hydrolysable sites. The result is not instant ethanol, but a more suitable feed for sugar production and fermentation.

A third benefit is compatibility with hot processing. Thermostable alpha-amylases are designed for conditions where ordinary proteins would unfold too quickly to remain useful. This allows liquefaction to occur close to the point where starch is gelatinized and accessible, instead of requiring the process to cool before any enzymatic action can begin [3].

Figure 7. Starch-based ethanol relies on amylolytic liquefaction and saccharification, whereas lignocellulosic ethanol requires pretreatment and cellulase or hemicellulase systems.

A fourth benefit is feedstock flexibility within starch-rich materials. Corn, cassava, sorghum, rice, sago, tapioca residues, and starch-containing food waste differ in granule structure and composition, but all contain α-glucan polymers that can be liquefied enzymatically when accessible. Research across these substrates shows why starch hydrolysis remains central to ethanol and fermentation processes [11].

These benefits should be understood within the full ethanol process. Final ethanol yield depends on feedstock composition, cooking and liquefaction effectiveness, saccharification, fermentation organism performance, solids handling, and ethanol recovery. Thermostable alpha amylase is a core liquefaction tool, not a standalone replacement for the rest of the process.

Product context for Enzymes.bio buyers

Enzymes.bio supplies Thermostable Alpha Amylase Enzyme for Industrial Ethanol Production for buyers who need a starch-liquefying enzyme for industrial ethanol and related starch-conversion applications. The product is available for direct online purchase by the 1 kg unit; after payment, the order is processed and shipped. A Certificate of Analysis and Safety Data Sheet are provided with the order.

The enzyme's role is clear: it helps convert hot, viscous starch mash into shorter dextrins and maltooligosaccharides so the material can move into saccharification and fermentation. That role is supported by the broader alpha-amylase literature and by ethanol studies using enzymatic hydrolysis for starch-rich crops, residues, and prepared food wastes [1].

Clear boundaries for correct use of the science

Thermostable alpha amylase should not be described as directly producing ethanol from starch. It does not ferment sugars, and it does not usually complete starch conversion to glucose on its own. Its main function is liquefaction: internal cleavage of α-1,4 starch bonds, viscosity reduction, and dextrin formation. Ethanol production still requires saccharification and microbial fermentation.

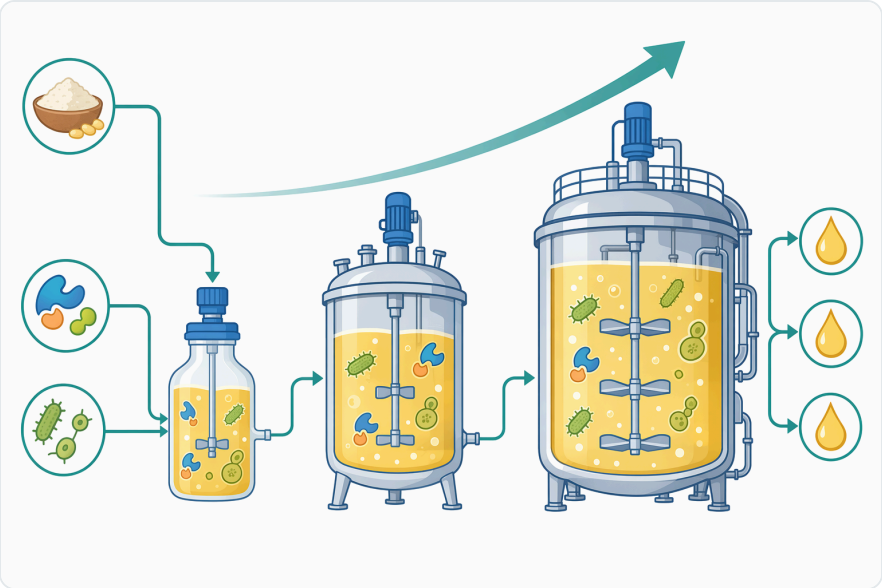

Figure 8. Published starch-to-ethanol work includes combined hydrolysis and fermentation evaluated from laboratory scale through pilot and industrial fermenter volumes.

It should also not be treated as a universal biomass enzyme. For lignocellulosic materials such as corn stover or sugarcane bagasse, pretreatment and cellulolytic enzyme systems are central because the main polymers are cellulose and hemicellulose rather than starch [16]. Alpha amylase is most relevant where starch is a significant carbohydrate fraction.

Finally, results from individual studies should be interpreted in context. A raw cassava starch process scaled from 5 L to 200 L and 3000 L demonstrates the promise of combined hydrolysis and fermentation, but it does not mean every starch feedstock behaves identically [8]. Barley granule-size research shows that even within one crop, starch structure can change hydrolysis behavior [13]. The reliable conclusion is that thermostable alpha amylase is a well-supported liquefaction enzyme class for starch-based ethanol processing, with performance shaped by the substrate and the overall process design.

Conclusion

Thermostable Alpha Amylase Enzyme for Industrial Ethanol Production is used to liquefy starch under hot processing conditions. It cleaves internal α-1,4 bonds in amylose and amylopectin, converting thick gelatinized starch into shorter dextrins and maltooligosaccharides. This reduces mash viscosity and prepares starch-rich material for downstream saccharification and fermentation.

The evidence base is strong at the process level: microbial alpha-amylases are established industrial starch-conversion enzymes; starch ethanol studies repeatedly rely on enzymatic hydrolysis before fermentation; and feedstocks such as cassava, sorghum, sago, rice, tapioca residues, and food waste have all been investigated through hydrolysis-and-fermentation routes. For buyers purchasing from Enzymes.bio, the product's purpose is therefore practical and specific: a 1 kg online-supplied thermostable alpha amylase for liquefying starch in industrial ethanol and related starch-conversion workflows.

References

Numbered in order of first citation. Open-access sources, each verified reachable at publication; citation numbers in the text link here.

1. Far, B. E., Ahmadi, Y., Khosroshahi, A. Y., & Dilmaghani, A. (2020). Microbial Alpha-Amylase Production: Progress, Challenges and Perspectives. *Advanced Pharmaceutical Bulletin*, 10, 350 - 358.
2. Permanasari, A. R., Yulistiani, F., Purnama, R., Widjaja, T., & Gunawan, S. (2018). The effect of substrate and enzyme concentration on the glucose syrup production from red sorghum starch by enzymatic hydrolysis. *IOP Conference Series: Earth and Environment*, 160.
3. Vala, V., Suhagia, T. A., Raina, V., Gurjar, A., Srivastava, S. K., Jain, P., & Alle, M. (2025). Thermostable amylases from thermophilic microbes: advances in production, engineering, and industrial applications. *Nanotechnology*, 37.
4. Abootalebi, S. N., Saeed, A., Gholami, A., Mohkam, M., Kazemi, A., Nezafat, N., Mousavi, S., … et al. (2020). Screening, Characterization and Production of Thermostable Alpha-Amylase Produced by a Novel Thermophilic Bacillus megaterium Isolated from Pediatric Intensive Care Unit.
5. Xian, L., Wang, F., Luo, X., Feng, Y., & Feng, J. (2015). Purification and Characterization of a Highly Efficient Calcium-Independent α-Amylase from Talaromyces pinophilus 1-95. *PLoS ONE*, 10.
6. Wangpor, J., Prayoonyong, P., Sakdaronnarong, C., Sungpet, A., & Jonglertjunya, W. (2017). Bioethanol production from cassava starch by enzymatic hydrolysis, fermentation and ex-situ nanofiltration.. *Energy Procedia*, 138, 883-888.
7. Chang, S., Chang, W., Maw-Lee, Yang, T., Yu, N., Chen, C., & Shaw, J. (2010). Simultaneous production of trehalose, bioethanol, and high-protein product from rice by an enzymatic process.. *Journal of Agricultural and Food Chemistry*, 58 5, 2908-14 .
8. Krajang, M., Malairuang, K., Sukna, J., Rattanapradit, K., & Chamsart, S. (2020). Single-step ethanol production from raw cassava starch using a combination of raw starch hydrolysis and fermentation, scale-up from 5-L laboratory and 200-L pilot plant to 3000-L industrial fermenters. *Biotechnology for Biofuels*, 14.
9. Sunaryanto, R., Handayani, B. H., & Safitri, R. (2013). Enzymatic and Acid Hydrolysis of Sago Starch for Preparation of Ethanol Production. *Microbiology Indonesia*, 7, 4.
10. Soeprijanto, S., Wulandari, S., & Alfaridzi, M. D. (2022). Bioethanol Production from Tapioca Solid Waste (Onggok) in a Batch Reactor.
11. Liu, Y., Han, W., Xu, X., Chen, L., Tang, J., & Hou, P. (2020). Ethanol production from waste pizza by enzymatic hydrolysis and fermentation. *Biochemical Engineering Journal*, 156, 107528.
12. Chen, X., Zheng, X., Pei, Y., Chen, W., Lin, Q., Huang, J., Hou, P., … et al. (2022). Process design and techno-economic analysis of fuel ethanol production from food waste by enzymatic hydrolysis and fermentation.. *Bioresource Technology*, 127882 .
13. Langenaeken, N., Schepper, C. D., Schutter, D. D. D., & Courtin, C. (2019). Different gelatinization characteristics of small and large barley starch granules impact their enzymatic hydrolysis and sugar production during mashing.. *Food Chemistry*, 295, 138-146 .

14. Souza, M. F., Rodrigues, M. A., Freitas, S., & Bon, E. (2020). Effect of milling and enzymatic hydrolysis in the production of glucose from starch-rich Chlorella sorokiniana biomass. *Algal Research-Biomass Biofuels and Bioproducts*, 50, 101961.
15. Barman, D., & Dkhar, M. S. (2023). Purification and characterization of moderately thermostable raw-starch digesting α-amylase from endophytic Streptomyces mobaraensis DB13 associated with Costus speciosus.. *Journal of General and Applied Microbiology*.
16. Sun, W., Li, X., Zhao, J., & Qin, Y. (2022). Pretreatment Strategies to Enhance Enzymatic Hydrolysis and Cellulosic Ethanol Production for Biorefinery of Corn Stover. *International Journal of Molecular Sciences*, 23.
17. Raj, K., & Krishnan, C. (2020). Improved co-production of ethanol and xylitol from low-temperature aqueous ammonia pretreated sugarcane bagasse using two-stage high solids enzymatic hydrolysis and Candida tropicalis. *Renewable Energy*, 153, 392-403.
18. Eom, I., Yu, J., Jung, C., & Hong, K. (2015). Efficient ethanol production from dried oil palm trunk treated by hydrothermolysis and subsequent enzymatic hydrolysis. *Biotechnology for Biofuels*, 8.