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BIOPROCESSING of AGRICULTURAL WASTES for VALUE ADDED BACTERIAL AMYLASE PRODUCTION

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Potential amylase enzymes have many industrial applications that are found in biological sources like animal, plants and microorganisms. Fungi and bacteria hold tremendous potential to produce the α-amylases using agriculture by-products under solid state fermentation (SSF). Agro-industrial residues such as rice bran, wheat bran, sugar cane bagasse, corn leaf, barley, orange peel, wheat straw, rice straw is abundant and cheapest carbon source. SSF using agro-industrial residues is currently used in a range of applications including classical applications such as antibiotics production, enzymes, composting, bio-surfactants and biofuel production. Microbial α-amylases have several applications in paper, food, pharmaceutical, detergent, and textile industries. The enzyme α-amylase is meritorious due to their properties such as thermostability, Ca^{2+}-independent pH stability and pH profile which play important role in the development of bioprocess of different products. This review is focused on physiochemical properties of the bacterial α-amylases fermentation, structural and functional aspects of agro industrial residues and by products for α-amylase production.
Keywords: agriculture by-products, agriculture residue, α-amylase, solid state fermentation.

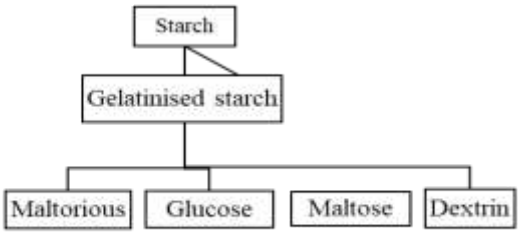
INTRODUCTION

In starch the catalysis of internal α- 1, 4-glycosidic affinity is determined by endo-amylases family of enzymes into simple sugar components like maltose, glucose and maltotriose units (Ahmed *et al*., 2017; Ait Kaki *et al.,* 2017). Amylases possess 25% share in world enzyme market because of their industrial importance they hold for biotechnological products with special enzymatic phylogeny (Gargiupadyay and Dharaniaiyer, 2016). This enzyme can be isolated from various biological sources including animals, microorganisms and plants. Amylases from microbial source have a great significance over animal and plant α-amylases because of their broad spectrum industrial appliances (Aarti *et al.,* 2017; Mushtaq *et al.,* 2017). Besides, bacterial amylases are subjugated as bio-resource in enzyme processing industries due to their constancy at harsh situations, rapid growth, accessibility for genetic manipulations, cost-effectiveness, easy maintenance and enhanced enzymatic activity at optimized variables to acquire enzymes of preferred characteristics (Aarti *et al.,* 2017; Nawaz *et al.,* 2017). α-amylases have impending use in a widespread of industrial progressions such as fermentation, food, detergent, paper, pharmaceutical and textile industries (Ait Kaki *et al.,* 2017; Mushtaq *et al.,* 2017). Presently, for the food of domestic cattle and domestics heating agriculture residues such as rice bran, wheat bran, sugar cane bagasse's, corn leaf, barley, orange peel, wheat straw, rice straw are being considered as a main source (Purohit and Munir et al., 2006). Synergistic uses of heat production and biofuel are totally dependent on agricultural waste in substantial amount in developing countries (Demirbas *et al.,* 2009). Solid state fermentation offers many of the promising advantages because of their natural potential of resistivity. Natural habitat of SSF found compatibility with microorganism habitat due to which microorganisms have optimum value added enzyme production and have a higher growth rate in that condition (Noraziah *et al.,* 2017; Santiago *et al.,* 2014). Fungi are more sensitive towards high water activity that's why submerged fermentation (SmF) is not indispensable for fungal growth (Santiago *et al.,* 2014).

Utilization of low cast agriculture wastes for the potential industrial enzymes is one of the agro-biotechnological perspective. The present review pointed out different types of agriculture by products and residues utilization by microorganisms for α-Amylase production.

Structural and functional characteristics of α -Amylase

Starch Hydrolysis Scheme: Starch is gelatinized under high temperature, in step one; α-amylase action on gelatinized starch leads to the production of glucose, maltose, maltotriose and dextrins. In second step α-amylase action on dextrin's leads to the production of glucose, maltose and maltotriose. While in third step; β- amylase acts on gelatinised starch and dextrins to only give maltose (Mushtaq *et al.,* 2017).



The amylase has a three-dimensional structure capable of binding to substrate and, by the action of highly specific catalytic groups, promote the breakage of the glycoside links (Xiea *et al.,* 2014). The human α-amylase is a classical calcium-containing enzyme composed of 512 amino acids in a single oligosaccharide chain with a molecular weight of 57.6 kDa (Ait Kaki *et al.,* 2017; Xiea *et al.,* 2014). The protein contains 3 domains: A, B, and C (Fig 1). The A domain is the largest, presenting a typical barrel shaped $(\beta/\alpha)_8$ super structure. The B domain is inserted between the A and C domains and is attached to the A domain by disulphide bond. The C domain has a β sheet structure linked to the A domain by a simple polypeptide chain and seems to be an independent domain with unknown function. The active site (substrate-binding) of the α-amylase is situated in a long cleft located between the carboxyl end of the A and B domains. The calcium (Ca^{2+}) is situated between the A and B domains and may act in the stabilization of the three-dimensinoal structure and as allosteric activator. Binding of substrate analogs suggest that Asp206, Glu230 and Asp297 participate in catalysis (Butterworth *et al.,* 2011; El-Enshasy *et al.,* 2013; Tiwari *et al.,* 2017). The substrate-binding site contains 5 subsites with the catalytic site positioned at subsite 3. Substrate can bind to the first glucose residue in subsite 1 or 2, allowing cleavage to occur between the first and second or second and third glucose residues (Muralikrishnaa and Nirmala, 2005).

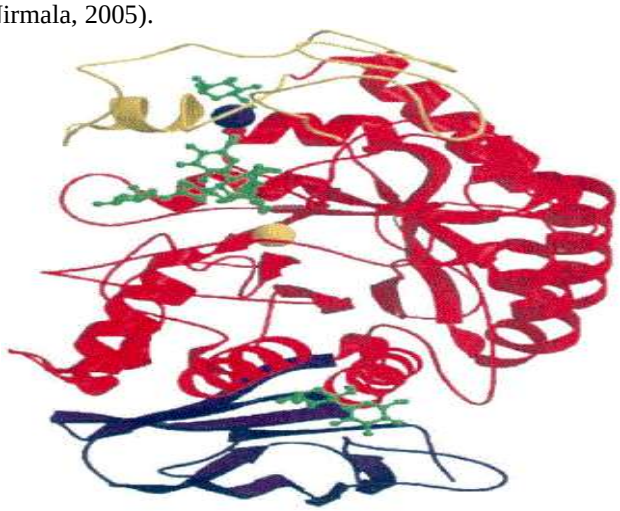


Figure 1. Structure α-amylase: red indicated A domain, yellow indicated B domain and C domain shown in purple (SP Tiwari et al., 2017).

***Amylase fermentation*:** The enzyme α-amylase is produced in both state of fermentations i.e submerged fermentation (SmF) and solid state fermentation (SSF) which shows dependency on different physicochemical factors (Mushtaq *et al.,* 2017). The SmF have more advantages then SSF when it is traditionally used for the industrial valuable catalyst production with effect of affluence in control of different parameters (Diaz *et al.,* 2016; Mushtaq *et al.,* 2017).

SSF offers many of the promising advantages because of their natural potential of resistivity to harsh fermentation environment. Natural habitat of SSF found compatibility with microorganism habitat due to which microorganisms have optimum value added enzyme production and have a higher growth rate in that condition (Yazid *et al.,* 2017; Santiago *et al.,* 2014). In SmF fungal growth is not indispensable as compare to SSF due to fungal high sensitivity to higher water activity. According to theoretical perception yeast and fungi were considered more appropriate microorganisms on the basis of water activity in SSF, however it is reported that bacteria have been thought out less activity in SmF (Santiago *et al.,* 2014). Different experiments have proven that in SSF processes bacterial cultures are best to manipulate and easy to manage fermentation process (Bozic *et al.,* 2014). While SSF have several benefits over SmF like lower capital investment, no foaming, less water activity, simpler technique, superior productivity, lower energy requirement, and better product recovery and moreover it is conveyed to be the most applicable practice for developing countries. By comparing titers of enzyme activity articulated between SSF and SmF, the SSF expresses higher enzymatic activities that is remarkable progress of SSF in the enzyme market (Núñez *et al.,* 2017; Noraziah *et al.,* 2017).

Optimization of the physical and chemical parameters are necessary for fermentation process as it promote more industrial applications and enhance the economy as well (Mushtaq *et al.,* 2017). α-amylase production has been defendant on different influences like nitrogen source, pH, temperature, phosphate, surface acting agents and carbon metal ions (Ashok and Kumar, 2017; Nawaz *et al.,* 2017). α-amylase properties depend on the pH stability, thermostability, Ca^{2+}-independency and pH profile according to their processing conditions like detergent industry require high pH and starch processing industries require low pH α-amylases (Tiwari *et al.,* 2017). Furthermost remarkable are phosphate concentration, pH of the medium, composition of the growth medium, aeration, inoculum age, temperature, nitrogen source and carbon source (Min *et al.,* 2015).

***Bacterial α-Amylases*:** Although many microorganisms are suitable for α-Amylase production, but for commercial purpose genus *Bacillus* is popular source for α-amylase production (Ahmed *et al.,* 2017; Nawaz *et al.,* 2017). *Bacillus* species like *Bacillus licheniformis*, *Bacillus amyloliquefaciens* and *Bacillus stearothermophilus* are reported for potential bacterial α-Amylase production stand

Table 1. Indicates physiochemical properties of microorganisms producing α-amylase

Microorganisms	Fermentation	Ph	Temperature	Inhibitors	References
Bacillus sp. KC887503	SSF	6.0-8.0	60-90		(Bozic et al., 2014)
B. licheniformis SHG10	SSF	3-11	50		(Embaby et al., 2014)
B. amyloliquefaciens	SmF	7.0	50		(Gargiupadyay et al., 2016)
Bacillus subtilis K-18	SSF	5.0	50		(Mushtaq et al., 2017)
B.licheniformis KIBGE IB	SSF	7.0	40		(Panda and Ray, 2015)
B.subtilis KCC103	SSF	6.0	60		(Rajagopalan & Krishnan, 2008)
BACILLUS SP	SSF	6	50	C_OCl_2 and NaCl	(Rajshree and Singh, 2011)
Bacillus megatherium	SSF	7.0	50		(Reda et al., 2014)
Bacillus methylotrophicus	SmF	7.0	70		(Xiea et al., 2014)
B. subtilis JS-2004	SmF	8.0	70	Co_2^+, Cu^+ and Hg_2^+	(Asgher et al., 2007)
Bacillus sp. DR90	SmF	4.0	45	Hg_2^+, Zn_2^+	(A. Asoodeh et al., 2013)
Bacillus sp. Ferdowsicous	SmF	4.5	70	Hg_2^+	(Ahmad Asoodeh et al., 2010)
Bacillus subtilis KIBGE HAS	SmF	7.5	50		(Bano et al., 2011)
Rheinheimera aquimaris	SmF	9.0	50		(Ghasemi et al., 2010)
Bacillus sp. KR-8104	SSF	4	70		(Maryam Hashemi, et al., 2013)
	SmF	4	60		
Bacillus mojavensis A21	SmF	6.5	80	EDTA	(Hmidet et al., 2010)
BKL20	SmF	6.0-11.0	60 -70 8C		(Kubrak et al., 2010)
Bacillus Licheniformis, *Gracilibacillus*, *βproteobacterium*	SmF	7.0-7.5	40		(Mahmoudnia et al., 2013)
Geobacillus thermodenitrifican	SmF	5-7	80	EDTA	(Mollania et al., 2010)
Bacillus licheniformis RBS 5	SmF	12	80	Cu^{2+}, Ca^{2+} & Mg^{2+}	(Rakia et al., 2016)
Bacillus acidicola TSAS1	SmF	7	33		(Sharm and Satyanarayana, 2011)
Bacillus alcalophilus JN21	SmF	9	50		(Yang et al.,2011)

with their several commercial applications such as in fermentation, textile, paper and food processing industries (Prakash and Jaiswal, 2010; Tiwari *et al.,* 2017).

For commercial applications only enzymes produce from thermophilic microorganisms are acceptable which have longer shelf life with thermo-stability. An enzymatic scarification and liquefaction of starch are accomplished by elevated temperatures (100–110ºC) and (80-90°C) respectively. Researchers are investigating more stable enzymes for cost effective products like dextrose syrup, crystalline dextrose, glucose, maltodextrins and maltose (Rasooli *et al.,* 2008). *Bacillus stearothermophilus* (Embaby *et al.,* 2014), *Bacillus subtilis* (Mushtaq *et al.,* 2017; Poddar and Jana, 2014), *Bacillus amyloliquefaciens* and *Bacillus licheniformis* (Nawaz *et al.,* 2017) are prominent because of their ability to produce thermo stable α-amylases which are industrially important and widely used for industrial consumptions (Prakash and Jaiswal, 2010; Tiwari *et al.,* 2017). Different bacterial strains are reported for thermostable α-amylases using both types of fermentation SSF as well as SmF (Tiwari *et al.,* 2017). α-amylase production in SSF is restricted to genus *Bacillus*, i.e., *B. megaterium*, *B. mesentericus, B. vulgarus, B. subtilis, B. licheniformis* and *B. polymyxia* while thermostable amylases of *B. stearothermophilus* or *Bacillus licheniformis* are being used in starch processing industries (Asoodeh *et al.,* 2013).

Halophilic microorganisms produces alkaline α amylases that have stability in concentrated salt solution processing industries due to which they got preference from other nonstable enzymes (Mahmoudnia *et al.,* 2013). In addition, halophilic bacteria which produce augmented halo-thermo tolerant have stability in high salt concentration with elevated temperature (Asoodeh *et al.,* 2010). Halophilic amylases can be characterized from both halophilic and non halophilic bacteria i.e Bacillus sp. strain GM8901 (Shin *et al.,* 2017), *Rheinheimera aquimaris*. (Ghasemi *et al.,* 2010), *Bacillus* sp. BKL20 (Kubrak *et al.,* 2010), Gracilibacillus (Mahmoudnia *et al.,* 2013), *Bacillus licheniformis* RBS 5 (Rakia Ben Salem *et al.,* 2016), *Bacillus halodurans* MS-2-5 and *Bacillus halodurans* 38C-2-1 (Yang *et al.,* 2011).

***Purification Ion exchange chromatography*:** Based on ionic and cationic bonds, the ion exchange chromatography (IEX) separates molecules on their surface charges. The negatively charged α- amylases can bind to the positively charged resins

and are eluted with different concentration of chloride ion. Other positively charged contaminants will flow out from the column without binding to the resins, while other negative charge contaminants are separated from α- amylase molecules depend on elution fraction (Tiwari *et al.,* 2017).

Size exclusion chromatography: Size- exclusion chromatography or gel filtration chromatography are often used for α- amylase purification. Protein of varying size are separated by columns consisting of a matrix of beads, which contains sieves of different of a size (Mahmoudnia *et al.,* 2013).

***Affinity column chromatography*:** affinity column chromatography purifies proteins according to their affinity towards a ligand. Such chromatography is also known as immobilization, which is commonly called immobilized metal affinity column chromatography (IMAC). When the analyte molecules in the crude enzyme interact with solid resin of IMAC, which has a covalent linkage with polydentate metal chelating group binding to a metal ion, surfaced exposed amino acids residues of the enzymes of interest will exchange with water molecule in metal coordination site, thus the enzyme immobilized (Nawaz *et al.,* 2017).

***Agro-Industrial Residues*:** South Asian regions (Bangladesh, Sri Lanka, India, and Pakistan,) contributes vital role in the regional economy due to their largest share in agriculture sector (Alauddin and Quiggin, 2008;).United Nations Environment Program (UNEP) reported that in south Asian region approximately every district produce round about 2.5 million tons of agriculture residues such as rice husk, rice straw, wheat straw, corn leaf, corn straw, sugar cane bagasse and corn cob etc. (Mirza *et al.,* 2008).

Rice husk (Oryza sativa) is one of the lignocellulosic residues (hemi-cellulose 4.80% w/w, cellulose 58.18% w/w, lignin 19.67% w/w and extractives 17.35% w/w) it attracts researchers due to its capability to be consumed as a biofuel. Rice husk as a raw material having low cost of money being used as a fertilizer, waste disposed, animal feeds or burnt as fuel. However, if rice husk is properly treated it will be used in saccharification and other value added products (Ang *et al.,* 2012). Wheat straw is composed of larger part of lignocellulose (48.78% cellulose, 22.5% hemicellulose and 18.64% lignin while small portion of 4.80% extractives and 5.28% ash. In many developing countries like Iran wheat straw is a main source for paper processing industries (Ghaffar *et al.,* 2017). Second generation bio ethanol that are produce from non-edible source of corn cob, this agro residue as like other agro-residues have same lignocellulose biomass consist of ash 1.6%, extractives 16.0%, hemicellulose 34.0% cellulose 30.0% and lignin 18.4%. In bioethanol production it is very challengeable and crucial step to hydrolyze hemicellulose and cellulose into monosaccharide with cost-effectiveness and efficiency (Xu *et al.,* 2017). When the liquid or juice removed from sugar cane the remaining large solid residue of sugar cane call bagasse. Which comprised small amounts of extractives 9.19% while varied lignocellulose components in huge amount like lignin 22.19%, hemicellulose 22.13%, cellulose 45.28% and ash 1.01%. Per ton of sugarcane about 250 kg of bagasse generated on that basis it is assumed that annually around 100 million tons of dry sugar cane bagasse are produced (Sarker *et al.,* 2017). Lignocellulose components in dry weight percentage and α amylase production from these agriculture residues are given in Table 2.

Subsequently lignin, cellulose and hemicellulose are the principal bio-components of these supplies; that can be consumed and reprocessed for production of several commercially interested products (Maitan-Alfenas *et al.,* 2015). Various authors extensively reported the valorization of lignocelluloses in sugarcane by-product processing industries with their possible applications (Bhatnaga *et al.,* 2016). Organic acids, biofuels (e.g. biohydrogen, biogas and ethanol), biosorbent, enzymes and compost fertilizer (Sarker *et al.,* 2017) are produced from agriculture residues. These products along with microorganisms are reported in (Table 2). Seven Annual years 2009-2015 agriculture production capita is indicated in Figure 2**.**

Table 2 Indicates physiochemical properties of microorganisms producing α-amylase

Residues	**Lignocellulose**			**Extractive**	**Ash**	**Ref**	**Microorganism**	**References**
	Cellulose	**Hemicellulos**	**Lignin**					
Corn Cob	30.00	34.00	18.40	16.60	1.6	(Xu *et al.,* 2017)	*Actinomycete*	(R.Singh *et al* 2012)
Rice Husk	53.18	4.63	19.67	17.35		(Ang *et al.,* 2012)		
Wheat Straw	49.78	20.55	19.46	4.93	5.2	(Kasman *et* al., 2011)	*Actinomycet*,B.AS1, *Aspergillus* sp. AS-2	(R. Singh *et al.,* 2012), (Bozic *et al.,* 2014)
Corn Leaf	29.74	30.14	9.25	30.87		(Danish *et al.,* 2015)	*Bacillus*.sp.AS1, *Aspergillussp*.AS2	(S. K. Soni *et al.,* 2003)
Corn straw	39.65	39.7	3.49	13.95	3.4	(Barten, 2013)	*Bacillus* sp,	(Bozic *et al.,* 2014)
Rice straw	38.30	21.4	15.1	7.30	17.9	(Karuna *et al.,* 2014)	*Aspergillus niger* P-19	(Chugh and Soni, 2016)
Bagasse	45.28	22.13	22.39	9.19	1.01	(Yao *et al.,* 2015) (Sarker *et al.,* 2017)	*Actinomycetes, Rhizopus microsporus*	(R. Singh *et al.,* 2012) (Fernández Núñez *et al.,* 2017)

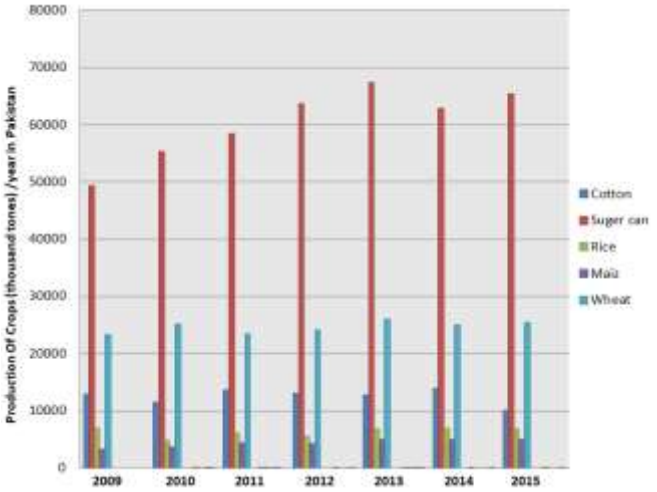


Figure 2. Seven Annual (2009-2015) agriculture production capita

At present, agriculture residues have two general domestic applications animal feeds and heating purpose (Purohit *et al.*, 2006). Due to significance of low cost materials and easy source of energy a revolutionary change come in the field of industries they consume million tons of agriculture by products in their industries (Chandel and Singh, 2011). Significant attempts have been made in recent years towards more efficient renewable agro-industrial residues utilization. About 30 million Pakistani lives in villages or urban areas, it is estimated that up to 30,000 villages are deprived from foremost energy basics of electricity and natural gas. As the agriculture wastes are broadly available in each village so applying renewable energy technique, they can develop their own energy source. This will be a milestone invention for reduction of energy crises in the whole country by increasing more energy development resources (Dincer, 2000).

AGRICULTURAL BY-PRODUCTS

Wheat Bran:

Composition and Function: Wheat (*Triticum aestivum*) is used for livestock feed and human consumption consists of three parts endosperm, bran and germ. The outer fraction of wheat is bran fraction known as wheat bran (WB) is used for food products and milling (Prückler *et al.*, 2014). Wheat bran (WB) was first used only for animal diet but now have importance over year by year due to human consumption. Worldwide, the quantity of WB-assimilated food yields improved from 52 million tons in 2001 to almost 800 million tons in 2011. This Bran is full of fiber, B vitamins, bioactive compounds and minerals which are famous to retain health endorsing qualities. Bakery and cereals foods are characterized based on Wheat Bran which share about 60% market value in these products. There is surprisingly increase in the demand of WB in cereal foods and baked foods because of high source of protein and safe to eat food (Onipe *et al.*, 2015; Prückler *et al.*, 2014).

***Rice Bran: Composition and Function*:** Rice (*Oryza sativa* L.) has a worldwide consumption as a major nutrition source but more precisely use in Asia for nourishment. It is estimated that nearby 680 million tons of rice are produced all over the world and shares equivalent to the wheat in production. Rice bran is the outer skin of rice and produce as a byproduct of rice processing. (Foo and Hameed, 2009). Rice bran attends different bioactive compounds and most delighted source of oil that show different effects on the activity of animal and humans cells (Henderson *et al.*, 2012).

Rice bran is the structural part of rice kernel which composed of aleuronic, subaleurone and pericarp fractions, in rice milling play role of byproduct. According to estimation rice bran have large contribution and produce 76 million tons annually in world market (Chiou *et al.*, 2013). Rice hulls, brans and oils amount for bioactive compounds, while rice brans are of two types i.e., white bran and pigmented bran, the latter contribute largest share of bioactive compounds (Friedman, 2013).

***Barley: Composition and Function*:** In cereal like rice, wheat and maize Barley (*Hordeum vulgare* L.) contributes as a 4th important in terms of cultivation area and production quantity. Although from last 5 years the production quantity of barley increase in 14 million reached to 114 million tones but harvesting decreased since 1980. Barley has uniqueness then other cereal likewise they are stable in harsh environment and can be cultivated in marginal lands i.e., near Arctic circle and high altitudes of the Himalayas (Corke *et al.*, 2004). There is variation in the morphological form of barley with great diversity like which include winter, spring, 2-row, 6-row, awnless, awned, hooded, naked (hull-less) and covered, malting, food type and feed (forage and grain) (Stanca *et al.*, 2016). Many researchers working for the novel genetic mutants and continuously reported the variation in composition of barley (Shaik *et al.*, 2016).

There is an abundant variety in the chemical structure of barley starches (ash, amylose, phosphorus-containing compounds, protein and lipid) (Table 3). The amylose content is a major factor affecting starch quality. Waxy, normal, and high amylose barley genotypes have been reported (Table 3). Waxy and high amylose genotypes were developed by genetic means (Shaik *et al.*, 2016; Zhu, 2017).

***Orange Peel: Composition and Function*:** The outer shell of orange is called Orange peel after consumption that is produced as a waste material, the waste material is properly treated in solid waste management it will have importance of sustainable economic development as well as environment friendly. Worrying about that the citrus fruit processing industries generate vast amounts of waste material, which cause important disposal difficulties (Pandey *et al.*, 2000). The derivatization of isolated cellulosic substance may remove the waste disposal problem and earn economic

Table 3. Analysis of Selected Agricultural by products (% Wt. As Dry), for A Amylase Production

Agro-By Poduct	Carbohydrate	Protein	Lipid	Micronutrient mg/g	Vitamins mg/g	References	
Rice bran	16.25	14.55	22.02	-	E:0.10 B: 0.53	(Zarei *et al.,* 2017)	
	α-Amylase	(Chugh *et al.,* 2016; Nampoothiri *et al.,* 2009;Rajshre *et al.,* 2011; R. Singh *et al.,* 2012; Suganthi *et al.,* 2011)					
Wheat bran	Starch 9.10-38.9	9.60-18.6	33.4-63.0	P:900-1500 Mg:530-1030 Zn:8.3-14.0 Fe:1.9-34.0	E:0.13-9.5 B: 1.89	(Onipe *et al.,* 2015)	
	α- Amylase	(Alariya *et al.,* 2013; Goyal *et al* , 2005; M. Hashemi *et al.,* 2010; Nampoothiri *et al.,* 2009; Reda M El-Shishtawy *et al.,* 2014; Sarker *et al.,* 2017; S. K. Soni *et al.,* 2003)					
barley	Amylose 0.7-40.0	0.04-0.13	0.03-0.9	P:0.024	-	(Zhu, 2017)	A amylase
	α- Amylase	(G. Muralikrishnaa and Nirmala, 2005; Kadziola, Abe et al., 1994; Poddar and Jana, 2014; Stanca *et al.,* 2016; Zhu, 2017)					
Orange peel	Sugar 16.9	42.5	-	-	(Embaby *et al.,* 2014)		
	A- Amylase	(Embaby *et al.,* 2014; G.Prameela *et al.,* 2016; Uygut and Tanyildizi, 2016)					

significance. The cellulose acetate has versatile commercial uses. Generally Complex lignocellulolytic residues are considered as the best substrates (Poddar and Jana, 2014). Enzymes produced from orange peel on SSF medium shown constant pH before and after autoclaving the medium with optimized enzymatic activity. Previous studies have reported the successful hydrolysis of citrus peel waste into sugars and their subsequent conversion into ethanol (Singh *et al.,* 2011). In the dried citrus peels the fat content is low and rich in cellulose, hemicelluloses, proteins and pectin. Citrus peels are the major solid by-product and comprise around 50% of the fresh fruit weight in the citrus processing industry. The effect of nitrogen source and moistening agents on amylase activity was also determined under the optimized conditions of incubation period, temperature, initial pH, and substrate (Uygut and Tanyildizi, 2016).

***Conclusion*:** The present review focused on the effective production of bacterial α-amylases, their structure and a comparative study of extrinsic and intrinsic fermentation parameters. Researchers have proved that usage of agriculture residues as a substrate for α-amylase production is more economical comparatively to other synthetic medium. In addition, further research is needed for novel α-amylases production using low cost agriculture residue as a substrate for indigenous bacterial strains in SSF.

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