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Application of *Lactobacillus* and *Streptococcus* from Yoghurt for Kabachnik - Field Synthesis of α-Aminophosphonates and Evaluation of their Catalytic Activity Using Molecular Docking

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A B S T R A C T

A simple, efficient and environmentally process for one pot three component synthesis of α-aminophosphonates by the condensation reaction of diversity of substituted benzaldehyde, amine and triethyl phosphite in the presence of microorganisms and yoghurt as a catalyst at room temperature under solvent free condition is described. The reaction was carried out using bacterial strains *viz. Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*. Both the bacterial strains were equally efficient for the synthesis of α-aminophosphonates. Yoghurt containing both of these bacteria was found to be even more active as a catalyst in terms of reaction time. This green method provides α-aminophosphonates in good to excellent yields with high purity in very short reaction time. Molecular docking study was also done in order to further understand the increased catalytic activity of yoghurt as a function of microorganisms present in it. Interaction of substrate i.e. substituted benzaldehyde with crystal structure of dehydrogenase from *Streptococcus thermophilus* (PDB: 3DZB) and *Lactobacillus delbrueckii* ssp. *bulgaricus* (PDB: 2YQ4) was done to obtain moldock energy (kcal/mol).

Introduction

Development of environmentally benign synthetic methodologies for organic synthesis is one of the challenges to chemists. In addition, the process should be economically viable. Application of green chemistry principles in the field of synthesis has open new vistas for organic chemists to develop innovative, non-hazardous and economically viable processes (Anastas and Warner, 1998; Dichiarante *et al.*, 2010; Horvath and Anastas, 2007; Galuszka *et al.*, 2013). Majority of reactions use hazardous solvent or toxic catalyst. So, the reactions under solvent free condition employing natural catalyst are desirable. In literature a number of synthetic methods are reported in which natural catalysts like pineapple juice (Patil *et al.*, 2011), lemon juice (Patil *et al.*, 2012), clay (Habibi and Marvi, 2006; Ramesh and Raghunathan, 2009), phosphates (Zahouily *et al.*, 2006), animal bone (Riadi *et al.*, 2010) etc. has been employed. α- Aminophosphonates are important compounds as they have wide applications as enzyme inhibitors (Allen *et al.*,

1989), antibiotics (Atherton *et al.,* 1986), herbicides, fungicides, insecticides (Maier and Spoerri, 1991) and plant growth regulators (Emsley and Hall, 1976). Nucleophilic addition of phosphite to imines catalyzed by oxalic acid (Vahdat *et al.,* 2008), $Al(OTf_3)$ (Sobhani and Tashrifi, 2009), $FeCl_3$ (Rezaei *et al.,* 2009), heteropoly acids (Heydari *et al.,* 2007), $SbCl_3/Al_2O_3$ (Ambica *et al.,* 2008), sulfamic acid (Mitragotri *et al.,* 2008), $YbCl_3$ (Xu *et al.,* 2006), silica sulfuric acid (Yang *et al.,* 2009), $ZrOCl_2.8H_2O$ (Bhanushali *et al.,* 2009), ZnO (Kassaee *et al.,* 2009), $BiCl_3$ (Zhan and Li, 2005), Amberlite-IR 120 (Bhattacharya and Rana, 2008), PPh_3 (Tian *et al.,* 2009), TiO_2 (Hosseini-Sarvari, 2008), CAN (Kasthuraiah *et al.,* 2007) have been reported. However, some of the reported processes are associated with drawbacks like use of solvent, addition reagent, long reaction time, costly and moisture sensitive catalyst. In continuation to our program to develop environmentally benign synthetic methods (Agarwal *et al.,* 2014; Agarwal *et al.,* 2018; Agrwal *et al.,* 2014) we, herein, report the use of yoghurt as a catalyst, as a function of microorganisms present in it, for the synthesis of α- aminophosphonates.

Yoghurt is a one of the milk products of major importance in the Indian sub-continent. It is the most important fermented milk product used in India from times immemorial. The scale of production ranges from household level to industrial scale. To the best of our knowledge we are first to report the use of yoghurt as a catalyst for the synthesis of α-aminophosphonates. In addition, molecular docking study was done to obtain moldock energy (kcal/mol), to achieve an insight into the interaction of substrate i.e. substituted benzaldehyde with crystal structure of dehydrogenase from *Streptococcus thermophilus* (PDB: 3DZB) and *Lactobacillus delbrueckii* ssp. *bulgaricus* (PDB: 2YQ4) as a receptor.

Materials and Methods

Culture of microorganism

Bacterial strains of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* were obtained from Department of Microbiology, GB Pant University of Agriculture and Technology, Pantnagar. Strains were used individually as a catalyst for the synthesis of α-aminophosphonates.

General procedure for preparation of yoghurt

In the preparation of yoghurt, cow's milk was boiled in order to destroy viable organism, cooled to the body temperature and seeded with starter culture from an earlier batch. A starter culture contains combination of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* organism.

Milk was then kept in undisturbed condition at ambient temperature for 4-6 hrs. A smooth homogeneous product having an acidity of 0.9 to 1.0 percent acid was formed. This homogenous product was then stirred to get thick porous yoghurt which was then used as catalyst.

General procedure for the synthesis of α-aminophosphonates

A mixture of substituted benzaldehyde (5mmol), aniline (5mmol) and yoghurt/ *Streptococcus thermophilus*/ *Lactobacillus delbrueckii* ssp. *bulgaricus* (0.5g) was taken with triethyl phosphite (6mmol) in 100 ml round bottom flask and was stirred at room temperature (Scheme 1). After completion of the reaction as indicated by TLC, the reaction mixture was extracted with water and dichloromethane to give pure α-aminophosphonate.

Molecular docking

Molecular docking study was performed using software Molegro Virtual Docker (Version 2.3) (Bachwani and Kumar, 2011; Mahajan *et al.,* 2014; Thomsen and Christensen, 2006). The protein structure of target enzyme in PDB file and ligand (synthesized compound) in Mol file were imported in MVD, and bond orders, hybridization states, and angles were assigned if missing. Electrostatic type surface of protein was created. Potential binding sites of target protein were obtained by detecting maximum of 5 cavities setting parameters as molecular surface (expanded van der Waals), maximum number of cavities (n=5), minimum cavity volume (10), probe size (1.20), maximum number of ray checks (n=16), minimum number of ray hits (n=12), and grid resolution (0.80). Keeping all the parameters as default, docking wizard was used to obtain multiple poses and all docking calculations. The best one pose with lowest moldock score was selected manually. Using default parameters maximum 5 cavities were detected in the target protein for potential binding with selected best pose. Sphere center of center of protein with sphere radius 30-33 A° were selected for further docking studies. Moldock score or total energy (kcal/mol) was obtained for protein-ligand interaction (Ramathilagam *et al.,* 2013).

Results and Discussion

Synthesis of α-aminophosphonates

Yoghurt is a product obtained by lactose fermentation of cow or buffalo milk or mixed milk through the action of single or mixed strains of lactic acid bacteria. The starter used in the manufacture of yoghurt includes *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*. The chemical composition of yoghurt has been reported as fat ranging from 5-9%, protein 3.3-3.4%, ash 0.75 – 0.79% and lactic acid 0.5-1.1%. The pH of commercial yoghurt is usually in the range of 3.5–4.3 (Bamise and Bamise, 2008; Shima *et al.,* 2012). Reaction of substituted benzaldehyde with amines results in the formation of imines intermediates which subsequently reacts with triethylphosphite to produce the corresponding α-aminophosphonates. Further, to explore the possibility of catalytic activity of yoghurt as a function of microorgamisms present in it, the individual reaction was carried out using *Streptococcus thermophilus*/ *Lactobacillus delbrueckii* ssp. *bulgaricus* as catalyst. Percent (%) yield of α-aminophosphonates obtained by multicomponent reaction of substituted benzaldehyde, aniline and triethyl phosphite using yoghurt/ *Streptococcus thermophilus*/ *Lactobacillus delbrueckii* ssp. *bulgaricus* are presented in table 1. Moreover, substituted benzaldehyde with either electron-donating or electron-withdrawing substituent reacted efficiently, giving excellent yield.

Characterization data

IR spectra were recorded on Brucker FT-IR spectrophotometer using KBr pellets. ^{1}H NMR spectra were recorded on Brucker AVANCE II 400 MHz instrument using $CDCl_3$ with TMS as internal standard.^{1}H NMR and IR spectra of synthesized compounds are as follows:

Table 1, Entry A1: Diethyl [1-(phenyl)-1phenylamino] methylphosphonate

IR (KBr): 3396, 3212, 1685, 1625, 1265, 763 cm^{-1}.

^{1}H NMR ($CDCl_3$, TMS): δ (ppm) 1.2 (3H, t, OCH_2-CH_3), 1.35 (3H, t, OCH_2-CH_3), 3.55 (1H, m, OCH_2-CH_3), 3.7 (1H, m, OCH_2-CH_3), 4.15 (2H, m, OCH_2-CH_3), 5.15 (1H, br s, N-H), 4.6-4.7 (1H, dd, NH-CH), 6.95-7.55 (10H, m, Ar-H).

Table 1, Entry A2: Diethyl [1-(3-nitrophenyl)-1phenylamino] methylphosphonate

IR (KBr): 3280, 1592, 1269, 1108, 811 cm^{-1}.

^1H NMR ($CDCl_3$, TMS): δ (ppm) 1.35 (3H, t, OCH_2-CH_3), 1.6 (3H, t, OCH_2-CH_3), 3.6-3.75 (1H, m, OCH_2-CH_3),

4.25-4.35 (1H, m, OCH_2-CH_3), 4.5-4.7 (2H, m, OCH_2-CH_3), 5.25 (1H, br s, N-H), 5.4 (1H, dd, NH-CH-), 6.9-8.5 (9H, m, Ar-H).

Table 1, Entry A3: Diethyl [1-(4-chlorophenyl)-1phenylamino] methylphosphonate

IR (KBr): 3312, 3368, 1575, 1276, 1078, 767 cm^{-1}.

^1H NMR ($CDCl_3$, TMS): δ (ppm) 1.2 (3H, t, OCH_2-CH_3), 1.4 (3H, t, OCH_2-CH_3), 3.3-3.5 (1H, m, OCH_2-CH_3), 3.6-3.7 (1H, m, OCH_2-CH_3), 4.1 (3H, s, OCH_3), 4.3-4.4 (2H, m, OCH_2-CH_3), 4.7 (1H, br m, N-H), 5.1 (1H, dd, NH-CH-), 6.8-7.7 (9H, m, Ar-H).

Table 1, Entry A4: Diethyl [1-(4-hydroxyphenyl)-1phenylamino] methylphosphonate

IR (KBr): 3312, 3288, 1625, 1263, 1112, 764 cm^{-1}.

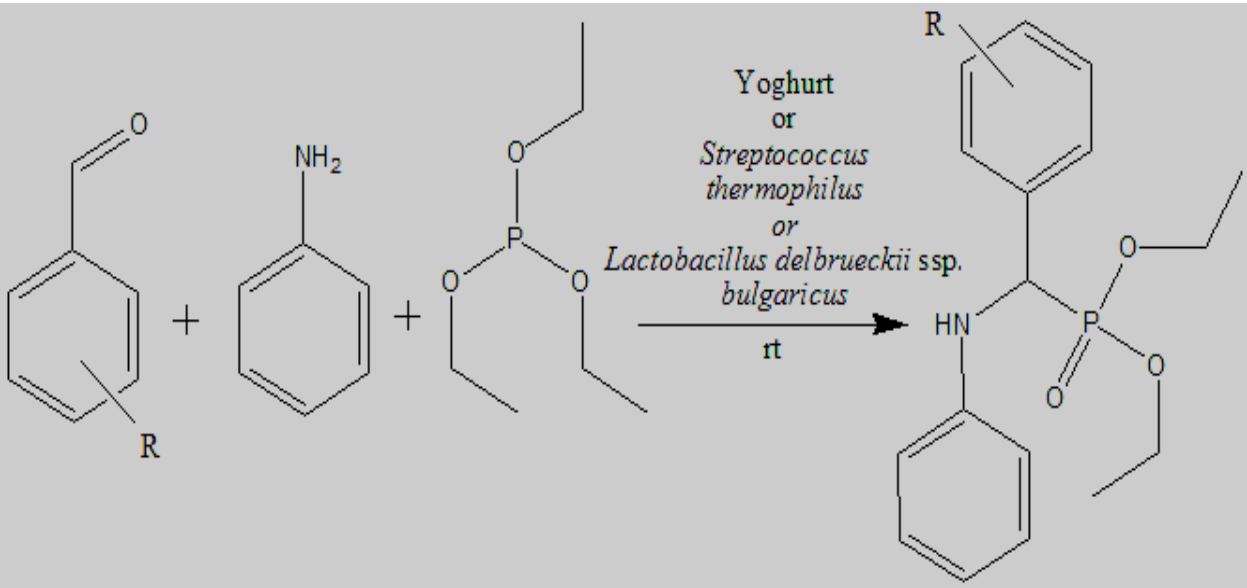
^1H NMR ($CDCl_3$, TMS): δ (ppm) 1.3 (3H, t, OCH_2-CH_3), 1.45 (3H, t, OCH_2-CH_3), 3.35-3.5 (1H, m, OCH_2-CH_3), 3.85-4.05 (1H, m, OCH_2-CH_3), 4.2 (3H, s, OCH_3), 4.45-4.6 (2H, m, OCH_2-CH_3), 4.85 (1H, br m, N-H), 5.1 (1H, br s, -OH), 5.4 (1H, dd, NH-CH-), 6.95-7.85 (9H, m, Ar-H).

Table 1, Entry A5: Diethyl [1-(4-methylphenyl)-1phenylamino] methylphosphonate

IR (KBr): 3383, 1265, 1047,784 cm^{-1}.

^1H NMR ($CDCl_3$, TMS): δ (ppm) 1.25 (3H, t, OCH_2-CH_3), 1.45 (3H, t, OCH_2-CH_3), 2.35 (3H, s, CH_3), 3.65 (2H, q, OCH_2-CH_3), 4.25 (2H, q, OCH_2-CH_3), 4.4 (1H, br m, N-H), 4.65 (1H, dd, NH-CH), 6.8-7.5 (9H, m, Ar-H).

Scheme.1 Synthesis of α-aminophosphonates in the presences of yoghurt/ *Streptococcus thermophilus*/ *Lactobacillus delbrueckii* ssp. *bulgaricus*



Scheme.2 Plausible mechanism of synthesis of α-aminophosphonates

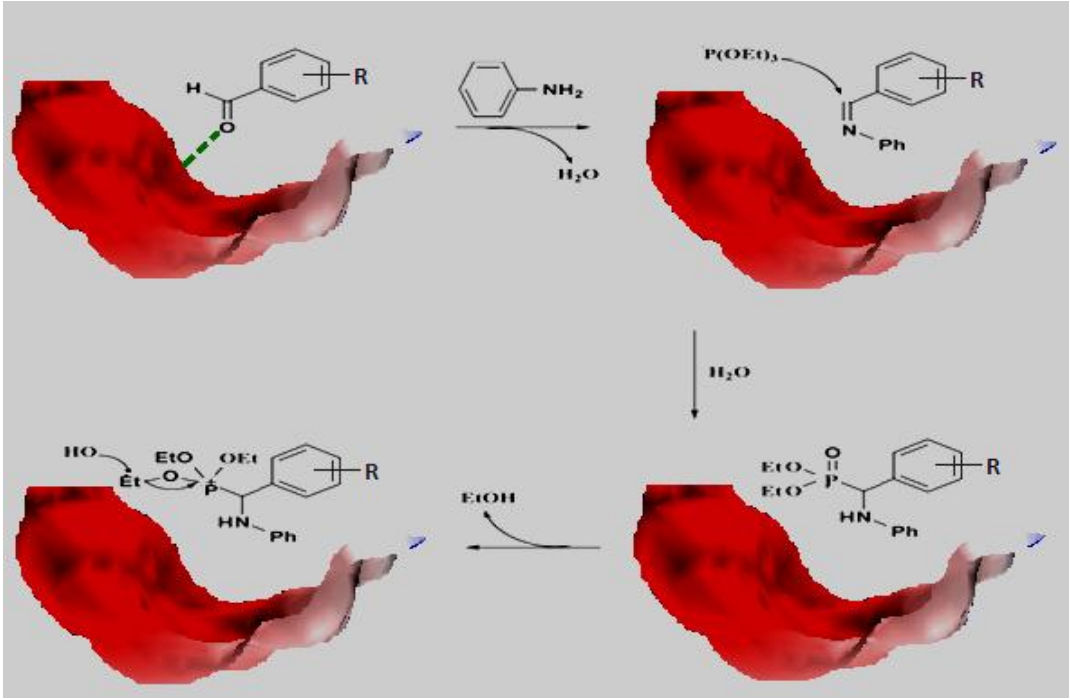
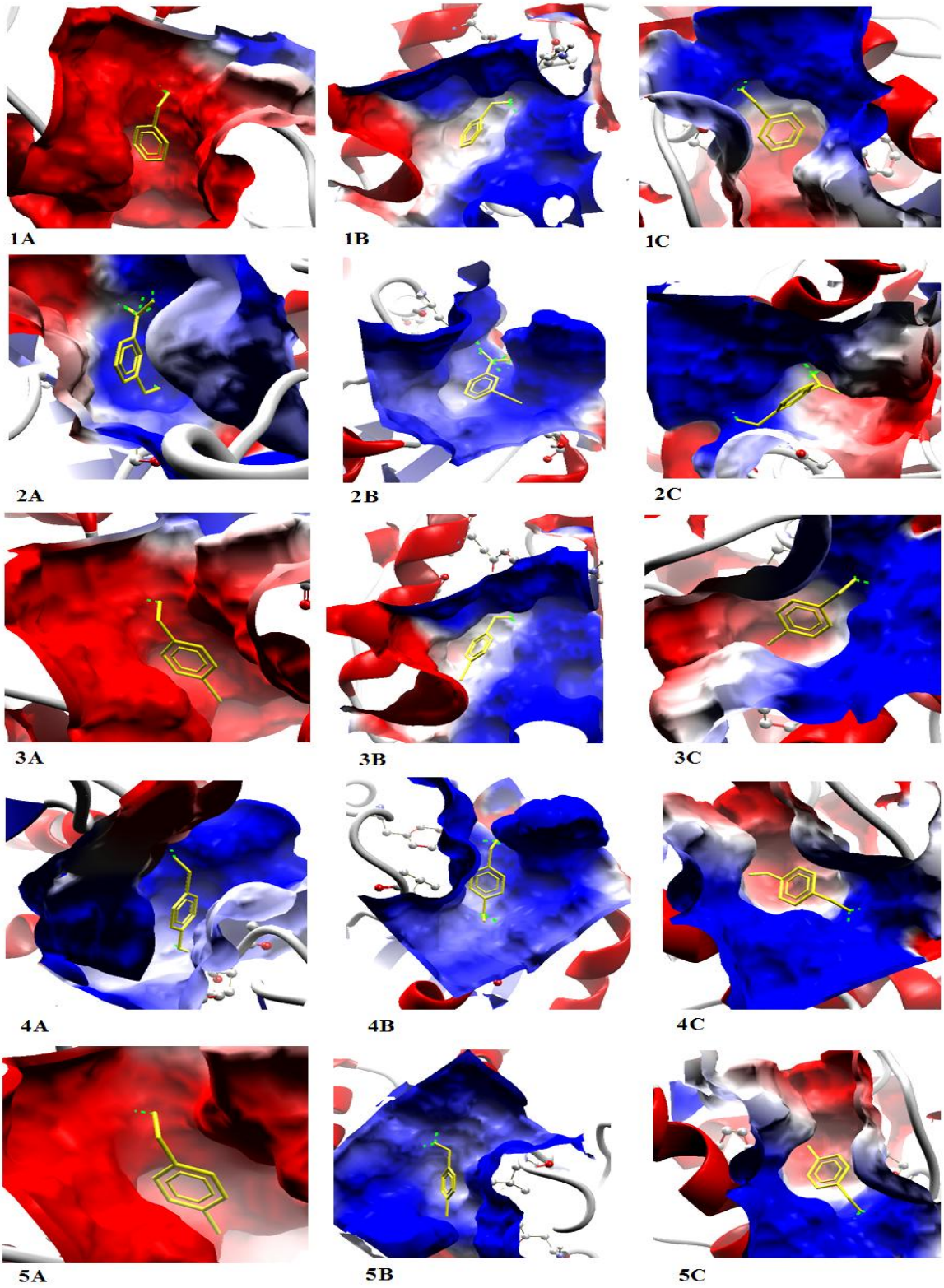


Table.1 Synthesis of α-aminophosphonates in the presence of microorganisms

Entry	Compound (R= Substituted Benzaldehyde)	Yoghurt containing both *Streptococcus thermophilus* (3DZB) and *Lactobacillus delbrueckii* ssp. *bulgaricus* (2YQ4)			*Streptococcus thermophilus* (3DZB)			*Lactobacillus delbrueckii* ssp. *bulgaricus* (2YQ4)		
		% Yield	Time (min)	MolDock Energy (kcal/mol)	% Yield	Time (min)	MolDock Energy (kcal/mol)	% Yield	Time (min)	MolDock Energy (kcal/mol)
A1.	R= H	89	4	-69.6	87	35	-53.8	85	30	-58.3
A2.	R= 3-NO_2	90	2	-84.3	86	20	-68.8	85	15	-67.7
A3.	R= 4-Cl	88	3	-79.1	82	25	-59.6	87	20	-61.1
A4.	R= 4-OH	85	3	-79.1	86	20	-62.6	84	30	-61.9
A5.	R= 4-CH_3	88	3	-79.6	87	30	-56.8	84	35	-61.8
A1: Diethyl [1-(phenyl)-1phenylamino] methylphosphonate					A2: Diethyl [1-(3-nitrophenyl)-1phenylamino] methylphosphonate					
A3: Diethyl [1-(4-chlorophenyl)-1phenylamino] methylphosphonate					A4: Diethyl [1-(4-hydroxyphenyl)-1phenylamino] methylphosphonate					
A5: Diethyl [1-(4-methylphenyl)-1phenylamino] methylphosphonate										

Fig.1 Interaction of substrate i.e. substituted benzaldehyde in the binding site of (1A-5A) - 2YQ4, (1B-5B) - 3DZB and (1C-5C) - both, 2YQ4 and 3DZB



Molecular docking

Interactions of substituted benzaldehyde with X-ray crystal structure of dehydrogenase from *Streptococcus thermophilus* (PDB: 3DZB), *Lactobacillus delbrueckii* ssp. *bulgaricus* (PDB: 2YQ4) obtained by molecular docking are presented in figure 1. In figure 1, images 1A-5A represents docking of substituted benzaldehyde with PDB: 2YQ4, images 1B-5B with PDB: 3DZB and images 1C-5C with both, PDB: 2YQ4 and PDB: 3DZB. Higher catalytic activity of yoghurt as compared to *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* can be explained on the basis of moldock energy (kcal/mol). Binding of substituted banzaldehyde with both crystal structures PDB: 2YQ4 and PDB: 3DZB gave rise to higher negative moldock energy as compared to *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus* (Table 1), explaining increased catalytic activity of yoghurt.

The role of microorganisms (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*) present in yoghurt as a catalyst has been proposed to increase the polarity of carbonyl group by binding with carbonyl oxygen which enhances the electrophilicity of the carbonyl carbon consequently increasing the reaction rate (leading high negative moldock energy (kcal/mol) (Table 1). The plausible mechanism of this reaction is believed to involve condensation between a carbonyl compound and an amine leading to *in situ* formation of the activated imine so that addition of phosphite is facilitated to afford phosphonium intermediate, which then undergoes reaction with water generated during the formation of imine to give α-aminophosphonates and ethanol (Scheme 2).

Thus, this article describes a simple and efficient method for the green synthesis of α-aminophosphonates derivatives through multicomponent one-pot protocol at room temperature under solvent-free condition using *Streptococcus thermophilus*, *Lactobacillus delbrueckii* ssp. *bulgaricus* and yoghurt as a function of microorganisms present in it. This method is found to be more advantageous as yoghurt offers the convenient, environmentally benign and inexpensive green approach for one pot synthesis of α-aminophosphonates within very short reaction time. Molecular docking on the basis of higher negative moldock energy (kcal/mol) described higher catalytic activity of yoghurt in comparison to *Streptococcus thermophilus*, *Lactobacillus delbrueckii* ssp. *bulgaricus* in terms of reaction time.

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References

Agarwal, D., Agrwal, A., Bairagi, A. and Kasana, V.K. (2014). Hydroxylamine Hydrochloride as an effective Catalyst for Formamide derivative Synthesis and their DPPH scavenging activity. Research Journal of Chemical Sciences. 4(10): 54-57.

Agarwal, D., Verma, A., Dhanik, J. and Kasana, V.K. (2018). Chemometric approach to evaluate catalytic activity of [CTAB/ 18-Crown-6]: A binary catalytic system for one pot green synthesis of 4-benzylidene-3-methylisoxazol-5(4H)-one derivatives at room temperature. International Journal of Chemical Studies. 6(2): 3003-3007.

Agrwal, A., Agarwal, D., Bairagi, A. and Kasana, V.K. (2014). A Mild and Environmentally benign Synthesis of Benzimidazoles: Relevance to the pectin hetero Polysaccharide as a Catalyst. Research Journal of Recent Sciences. 3: 64-67.

Allen, M.C., Fuhrer, W., Tuck, B., Wade, R. and Wood, J.M. (1989). Renin inhibitors. Synthesis of transition-state analog inhibitors containing phosphorus acid derivatives at the scissile bond. Journal of Medicinal Chemistry. 32: 1652-1661.

Ambica, Kumar, S., Taneja, S.C., Hundal, M.S. and Kapoor, K.K. (2008). One-pot synthesis of α-aminophosphonates catalysed by antimony trichloride adsorbed on alumina. Tetrahedron Letters. 49: 2208-2212.

Anastas, P.T. and Warner, J.C. (1998). Green Chemistry Theory and Practice. Oxford University Press, New York.

Atherton, F.R., Hassal, C.H. and Lambert, R.W. (1986). Synthesis and structure–activity relationships of antibacterial phosphonopeptides incorporating (1-aminoethyl) phosphonic acid and (amino-methyl) phosphonic acid. Journal of Medicinal Chemistry. 29: 29-40.

Bachwani. M. and Kumar, R. (2011). Molecular Docking: A Review. International Journal of Recent Advances in Ayurveda Pharmacy. 2(6): 1746-1751.

Bamise, C.T. and Bamise, O.F. (2008). Quantifying the acidic content of commercial yoghurt drinks in Nigeria. The Internet Journal of Dental Science. 6(1): 8401p.

Bhanushali, M.J., Nandurkar, N.S., Jagtap, S.R. and Bhanage, B.M. (2009). $ZrOCl_2 8H_2O$: An efficient catalyst for one-pot synthesis of α-aminophosphonates under solvent-free conditions. Synthetic Communications. 39: 845-859.

Bhattacharya, A.K. and Rana, K.C. (2008). Amberlite-IR 120 catalyzedthree-component synthesis of α-amino phosphonates in one-pot. Tetrahedron Letters. 49: 2598-2601.

Dichiarante, V., Ravelli, D. and Albini, A. (2010). Green chemistry: state of the art through an analysis of the literature. Green Chemistry Letters and Reviews. 3(2): 105-113.

Emsley, J. and Hall, D. (1976). The Chemistry of Phosphorous. Harper and Row, London.

Galuszka, A., Migaszewski, Z. and Namies, J. (2013). The 12 principles of green analytical chemistry and the significance mnemonic of green analytical practices. Trends in Analytical chemistry. 50: 78-84.

Habibi, D. and Marvi, O. (2006). Montmorillonite KSF and Montmorillonite K-10 Clays as Efficient Catalyst for the Solventless Synthesis a Bismaleimides and Bisphthlimides Using Microwave Irradiation. Arkivoc. 13: 8-15.

Heydari, A., Hamadi, H. and Pourayoubi, M. (2007). A new one-potsynthesis of α-amino phosphonates catalyzed by $H_3 PW_{12}O_{40}$. Catalysis Communications. 8: 1224-1226.

Horvath, I.T. and Anastas, P.T. (2007). Innovations and green chemistry. Chemical Reviews. 107: 2169-2173.

Hosseini-Sarvari, M. (2008). TiO_2 as a new and reusable catalyst for one-pot three-component syntheses of α-aminophosphonates insolvent-free conditions. Tetrahedron. 64: 5459-5466.

Kassaee, M.Z., Movahedi, F. and Masrouri, H. (2009). ZnO nanoparticlesas an efficient catalyst for the one-pot synthesis of α-aminophos-phonates. Synlett. 1326.

Kasthuraiah, M., Kumar, K.A., Reddy, C.S. and Reddy, C.D. (2007). Syntheses, spectral property, and antimicrobial activities of 6-α-amino dibenzo [d,f][1,3,2]dioxaphosphepin 6-oxides. Heteroatom Chemistry. 18: 2-8.

Mahajan, A., Gill, N.S. and Arora, R. (2014). A Review on Molecular Docking. International Journal of Recent Advances in Pharmaceutical Research. 4(2): 64-70.

Maier, L. and Spoerri, H. (1991). Organic phosphorus compounds. Resolution of 1-amino-2-(4-fluorophenyl) ethylphosphonic acid as well as some di- and tripeptides. Phosphorus, Sulfur and Silicon and the Related Elements. 61: 69-75.

Mitragotri, S.D., Pore, D.M., Desai, U.V. and Wadgaonkar, P.P. (2008). Sulfamic acid: An efficient and cost-effective solid acid catalyst for the synthesis of α-aminophosphonates at ambient temperature. Catalysis Communications. 9: 1822-1826.

Patil, S., Jadhav, D.S. and Mane, S.Y. (2011). Pineapple Juice as a Natural Catalyst: An Excellent Catalyst for Biginelli Reaction. International Journal of Organic Chemistry. 1: 125-131.

Patil, S., Jadhav, S.D. and Patil, U.P. (2012). Natural Acid Catalyzed Synthesis of Schiff Base under Solvent-free Condition: As a Green Approach. Archives of Applied Science Research. 4(2):1074-1078.

Ramathilagam, C., Upgade, A., Bhaskar, A., Umarani, P.R. and Manivannan, V. (2013). Synthesis and molecular docking studies of ethyl 1-benzenesulfonyl -2-[(E)-2-(2 methylphenyl) ethenyl] indole -3-carboxylate with human renin complexed with inhibitor. Asian Journal of pharmaceutical and Clinical Research. 6(4): 96-99.

Ramesh, E. and Raghunathan, R. (2009). Microwave-Assisted K-10 Montmorillonite Clay-Mediated Knoevenagel Hetero-Diels-Alder Reactions: A Novel Protocol for the Synthesis of Polycyclic Pyrano[2,3,4-kl]xanthene Deriva-tives. Synthetic Communications. 39(4): 613-625.

Rezaei, Z., Firouzabadi, H., Iranpoor, N., Ghaderi, A., Jafari, M.R., Jafari, A.A. and Zare, H.R. (2009). Design and one-pot synthesis of α-aminophosphonates and bis (α-aminophosphonates) by iron (III)chloride and cytotoxic activity. European Journal of Medicinal Chemistry. 44: 4266-4275.

Riadi, Y., Mamouni, R., Azzalou, R., Boulahjar, R., Abrouki, Y., Haddad, M.E., Routier, S., Guillaumet, G. and Lazar, S. (2010). Animal bone meal as an efficient catalyst for crossed-aldol condensation. Tetrahedron Letters. 51: 6715-6717.

Shima, A.R.R, Salina, H.F., Masniza, M., Atiqah, A.H. (2012). Viability of lactic acid bacteria in home made yogurt containing sago starch oligosaccharides. International Journal of Basic & Applied Sciences. 12(01): 58-62.

Sobhani, S. and Tashrifi, Z. (2009). One-pot synthesis of primary 1-aminophosphonates: coupling reaction of carbonyl compounds, hexamethyldisilazane and diethyl phosphite catalyzed by $Al(OTf)_3$. Heteroatom Chemistry. 20: 109-115.

Thomsen, R. and Christensen, M.H. (2006). Moldock: A New Technique for High-Accuracy Molecular Docking. Journal of Medicinal Chemistry. 49: 3315-3321.

Tian, Y.P., Wang, F., Xu, Y., Tang, J.J. and Li, H.L. (2009). PPh 3-catalysed one-pot three-component syntheses of α-aminophosphonates under solvent-free conditions. Journal of Chemical Research. 78-80.

Vahdat, S.M., Baharfar, R., Tajbakhsh, M., Heydari, A., Baghbanian, S.M. and Khaksar, S. (2008). Organocatalytic synthesis of α-hydroxyl and α-aminophosphonates. Tetrahedron Letters. 49(46): 6501-6504.

Xu, F., Luo, Y., Wu, J., Shen, Q. and Chen, H. (2006). Facile one-potsynthesis of α-amino phosphonates using lanthanide chloride ascatalyst. Heteroatom Chemistry. 17: 389-392.

Yang, J.J., Dang, J.N. and Chang, Y.W. (2009). Silica sulfuric acid as arecyclable catalyst for a one-pot synthesis of α-aminophosphonatesin solvent-free conditions. Letters in Organic Chemistry. 6: 470-473.

Zahouily, M., Mounir, B., Charki, H. Mezdar, A., Bah-Laouan, B. and Ouammou, M. (2006). Investigation of the Basic Catalytic Activity of Natural Phosphates in the Michael Condensation. Arkivoc. 13: 178-186.

Zhan, Z.P. and Li, J.P. (2005). Bismuth (III) chloride catalyzed three-component coupling synthesis of α-aminophosphonates. Synthetic Communications. 35: 2501-2508.

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