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综 述

在海洋环境中的酵母菌分布与多样性*

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摘 要： 最近几年作者对不同海洋环境中的酵母资源、分布和多样性进行的大量研究，从中发现了22属63种1051株。并且发现这些广泛分布在海水、海泥、高盐海水、深海、各种大型海藻表面、各种海鱼体表和体内和红树林生态系统中。不同种的酵母可以产生蛋白酶、脂酶、植酸酶、菊糖酶、纤维素酶、β-1,3-葡聚酶、嗜杀因子、核黄素、铁载体等活性产物，所以这些酵母菌具有广泛的实际用途。

关键词： 海洋环境；酵母菌；分布；多样性
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1 酵母菌细胞密度

海洋酵母通常是指在海水中比在淡水中生存时间更长的酵母菌，作者认为海洋酵母菌还应该指来自于真正海洋环境的酵母菌，并且与在淡水培养基中生长情况相比，在海水培养基中生长更好或生长不受影响，到目前为止还没有发现绝对依赖NaCl进行生长的酵母菌[1-2]。作者还发现很多陆地酵母在海水中并不能生长或生长不良。如果海洋酵母能作为工业生产酶制剂和活性产物用菌，作为制备培养基用的海水资源是十分丰富的，并且使用海水作为培养基可以节约大量淡水。

不管是淡水和海洋水环境都是酵母菌的常见来源[3]，淡水中酵母菌的密度大于海水[4]，但其密度的差异程度因污染程度的不同而变化。酵母菌在开放的大洋海水中的密度小于10 cells/L，在没有被污染的湖和海滨水中小于100 cells/L，在人迹罕至的阿根廷巴塔哥尼亚湖中检测到非常少的酵母菌[5]，在大洋水中只有当无脊椎动物和浮游植物大量繁殖时酵母菌的数量才有可能增加，能达到3×10^3 cells/L[6]。酵母菌总数通常随着污染物的增加而增加，在有时能够达到2×10^8 cells/L(在污水中)。在墨西哥湾流中酵母细胞的数量随着深度的不同变化很大[7]，在卡布拉尔海沟的表层海水中，酵母菌的平均数量为5.4 cells/L，并随着不同的深度而变化[8]。

酵母菌细胞数量在污染区的沉积物中超过100 cells/g[5]，酵母细胞在沉积物中的数量取决于沉积物的类型[9]，目前在深海海底，沙质的沉积物中没有检测出酵母菌菌落，而在深海热泉区域能够检测到酵母菌。Hagler等研究了巴西Rio de Janeiro遭污染的塞佩蒂巴湾的不同基质，用MPN法检测的海滨水中酵母菌的数量为3.7×10^3 cells/L，然而在同一位置泥类沉积物中的数量是水中的20倍，而在虾肠道中的数量是水中的400倍[10]；用MPN法检测的无脊椎动物的平均酵母菌数是水中的37倍[11]。在潮间带海湾沉积物中，用MPN法检测的酵母菌的数量是海水中的20～30倍[12]，相反，有的研究者认为，在无脊椎动物中的酵母菌比沉积物周围少，可能是酵母的营养细胞在无脊椎动物中的专性定位取决于不同种与环境之间的结合，在红树林的海水中酵母菌的数量从$10^4\sim10^5$ cells/L[13]。

2 酵母菌在海洋中的分布

地球表面71%被海洋覆盖，在那里存在着大量的生物资源，其中包括酵母、酵母基因、活性产物、酶资源[1]。在海洋环境发现的主要酵母菌属包括短梗霉(*Aureobasidium*)、假丝酵母(*Candida*)、隐球酵母(*Cryptococcus*)、德巴利酵母(*Debaryomyces*)、黑粉菌(*Filobasidium*)、半乳糖霉菌(*Galactomyces*)、地霉(*Geotrichum*)、有孢汉逊酵母(*Hanseniaspora*)、伊萨酵母(*Issatchenkia*)、克鲁维酵母(*Kluyveromyces*)、柯达酵母(*Kodamaea*)、路德酵母(*Lodderomyces*)、梅奇酵母(*Metschnikowia*)、毕赤酵母(*Pichia*)、红冬孢酵母(*Rhodosporidium*)、红酵母(*Rhodotorula*)、酿酒酵母(*Saccharomyces*)、丝孢酵母(*Trichosporon*)、拟威尔酵母(*Williopsis*)、耶罗维亚酵母(*Yarrowia*)、接合拟威

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尔酵母(*Zygowilliopsis*)、木拉克酵母(*Mrakia*)、久浩酵母(*Guehomyces*)、囊酵母(*Zygoascus*)、棒孢酵母(*Clavispora*)等和一些未确定属的酵母(见网站:http://www.mccc.org.cn)。因此很有必要对海洋酵母进行深入研究,从中获取活性产物、酶和基因资源。

本实验室从南极、中国东海、南海、黄海、山东蓬莱、长岛、荣成、石岛、青岛胶州湾、沙子口、东风盐场、大麦岛、石老人、太平角、小港、栈桥、天津大港区、海口文昌、演丰镇等地的海水、沉积物、生物样品中取样,对分离酵母菌进行鉴定,得到的酵母菌分布情况如下:

2.1 酵母菌在表层海水中的分布

在黄海的水样中得到了较多的近平滑假丝酵母(*Candida parapsilosis*)(15株)、念珠假丝酵母(*Candida aaseri*)(7株)、胶红酵母(*Rhodotorula mucilaginosa*)(4株)、解脂耶罗威亚酵母(*Yarrowia lipolytica*)(14株)、近平滑假丝酵母(*Candida parapsilosis*)(15株),此外还分离到球红冬孢酵母(*Rhodosporidium sphaerocarpum*)(1株)、热带假丝酵母(*Candida tropicalis*)(1株)、涎沫假丝酵母(*Candida zeylanoides*)(1株)、西方伊萨酵母(*Issatchenkia occidentalis*)(1株)、指甲毕赤酵母(*Pichia onychis*)(1株)、季也蒙毕赤酵母(*Pichia guilliermondii*)(1株)、金黄色隐球酵母(*Cryptococcus aureus*)(1株),二尖梅奇酵母(*Metschnikowia bicuspidata*)(2株)等。在青岛近表层海水中分离到了汉逊德巴利酵母(*Debaryomyces hansenii*)(34株)、解脂耶罗威亚酵母(*Yarrowia lipolytica*)(15株)、热带假丝酵母(*Candida tropicalis*)(12株)、季也蒙毕赤酵母(*Pichia guilliermondii*)(6株)、涎沫假丝酵母(*Candida zeylanoides*)(6株)、出芽短梗霉(*Aureobasidium pullulans*)(2株)等。

从南极水样中分离到解脂耶罗威亚酵母(*Yarrowia lipolytica*)(3株)、汉逊德巴利酵母(*Debaryomyces hansenii*)(3株)、胶红酵母(*Rhodotorula mucilaginosa*)(1株)、出芽短梗霉(*Aureobasidium pullulans*)(1株)和普兰久浩酵母(*Guehomyces pullulans*)(1株)等酵母。

作者发现从这些环境分离到的几株海洋酵母普鲁兰类酵母(*Aureobasidium pullulans*)能够生产蛋白酶。蛋白酶可以用于各种海洋生物蛋白的水解提高蛋白质产品的高附加值,用于生产生物活性肽[14]。生物活性肽具有很多重要的生物学功能,比如免疫调节效应,抗氧化活性,抗高血压活性,抗微生物活性[15]。其中一株普鲁兰类酵母(*Aureobasidium pullulans*)HN2.3产生的碱性蛋白酶水解毛虾蛋白产生的短肽ACE抑制活力要比其他酵母碱性蛋白酶的高,可达88.3%[16]。但是很遗憾,这种活性肽都没有抗微生物活性。所以这些酵母在医药工业、食品工业、化学工业、饲料工业等方面有重要的用途[14]。同时我们发现某些普鲁兰类酵母(*Aureobasidium pullulans*)菌株能够产生嗜杀因子[17]和脂酶[19]。

其中的金黄色隐球酵母(*Cryptococcus aureus*)G7a在人工海水培养基中可以产生85 U/mL的菊糖酶,所产生的粗酶水解菊糖可以产生大量的单糖和寡糖[20]。尤其是海水中NaCl和$MgCl_2$对该酶合成有很明显的刺激作用。菊糖酶可以将菊糖水解成果糖用于生产高果糖。同时,该菌株的蛋白含量非常高,达到细胞干重的41.4%[21],因此在食品、饮料和医药方面有许多重要的用途[22]。

分离得到1株桔假丝酵母(*Candida quercitrusa*)JHSb和1株解脂耶罗威亚酵母(*Yarrowia lipolytica*)N9a能够产生植酸酶,因此在饲料工业方面有非常重要的用途[18]。

分离筛选得到的另外1株普鲁兰类酵母(*Aureobasidium pullulans*)JHsc其纤维素(CMC)酶活力达到4.51 U/mg,滤纸酶活达到4.57 U/mg[23]。纤维素酶可以和酒精酵母共同作用与纤维素可以生产燃料酒精,作为洗涤剂的添加剂和转化纤维素生产葡萄糖,可以生产纤维素酶的酵母菌可以用于转化秸秆中的纤维素生产单细胞蛋白[20],因此产纤维素酶的酵母菌用途非常广泛。

还分离到1株普鲁兰类酵母(*Aureobasidium pullulans*)HN6.2菌株能够分泌一种铁载体,能够抑制鳗弧菌和副溶血弧菌的生长[45],因此在水产养殖业有重要的用途。

此外从中国东海海水中分离到1株产膜假丝酵母(*Candida membranifaciens* subsp. *flavinogenie*)W14-3菌株,在以木糖、蔗糖、半乳糖和麦芽糖为碳源的液体培养基中,能够产生大量的核黄素[25],因此在食品、医药和工业生产中有着重要的用途。

2.2 酵母菌在红树林中的分布

在红树林生态系统中酵母菌群落呈现出非常大的差异,其中担子菌类的酵母与其他水域相比,种群多样性没有什么太多显著地差异,甚至其多样性要更低。但是子囊菌类的酵母相对于其他水域,其种群数量明显要多[10-13,26-27]。在红树林生态系统中,许多子囊类种群是外来的,而且往往只能发现有代表性的几个种,因此明显的优势种是不存在的[11]。在受到污染的水域中,担子菌类的酵母的数量要少于子囊菌类酵母[4]。水环境中的担子菌类酵母数量要高于沉积物和无脊椎动物体的数量,这可能是因为担子菌类酵母通常是好氧菌,在海水表层的数量比较多。

本实验室在厦门红树林沉积物中发现热带假丝酵

母(*Candida tropicalis*)(17株)和海泥克鲁维酵母(*Kluyveromyces aestuarii*)(5株)占优势，此外还分离到博伊丁假丝酵母(*Candida boidinii*)(1株)、东方伊萨酵母(*Issatchenkia orientalis*)(3株)、土星拟威尔酵母(*Williopsis saturnus*)(2株)、斯巴达克毕赤酵母(*Pichia spartinae*)(1株)、墨西哥毕赤酵母(*Pichia mexicana*)(1株)、异常毕赤酵母(*Pichia anomala*)(1株)、麦芽糖假丝酵母(*Candida maltosa*)(1株)和近平滑假丝酵母(*Candida phangngensis*)(1株)等。在海南红树林沉积物中分离到了热带假丝酵母(*Candida tropicalis*)(14株)、汉逊德巴利酵母(*Debaryomyces hansenii*)(5株)、近平滑假丝酵母(*Candida phangngensis*)(3株)、链状假丝酵母(*Candida catenulata*)(5株)、白假丝酵母(*Candida albicans*)(2株)、浅白隐球酵母(*Cryptococcus albidus*)(1株)、博伊丁假丝酵母(*Candida boidinii*)(1株)、土星拟威尔酵母(*Williopsis saturnus*)(1株)等。

在红树林的植物上分布的酵母有热带假丝酵母(*Candida tropicalis*)(51株)、汉逊德巴利酵母(*Debaryomyces hansenii*)(11株)、阿萨丝孢酵母(*Trichosporon asahii*)(6株)、奥默柯达酵母(*Kodamaea ohmer*)(14株)、东方伊萨酵母(*Issatchenkia orientalis*)(5株)、海泥克鲁维酵母(*Kluyveromyces aestuarii*)(5株)、汉逊德巴利酵母(*Debaryomyces hansenii*)(14株)、季也蒙毕赤酵母(*Pichia guilliermondii*)(4株)、简型假丝酵母(*Candida intermedia*)(14株)、胶红酵母(*Rhodotorula mucilaginosa*)(3株)、脂耶罗威亚酵母(*Yarrowia lipolytica*)(6株)、近平滑假丝酵母(*Candida phangngensis*)(7株)、链状假丝酵母(*Candida catenulata*)(9株)、墨西哥毕赤酵母(*Pichia mexicana*)(5株)、出芽短梗霉(*Aureobasidium pullulans*)(2株)、乳酪假丝酵母(*Candida butyri*)(8株)、异常毕赤酵母(*Pichia anomala*)(7株)、林木假丝酵母(*Candida silvae*)(3株)、白假丝酵母(*Candida albicans*)(2株)。这说明在热带和亚热带生长的红树林植物上热带假丝酵母菌占有很大的比例，这可能与这些环境受到严重污染有很大的关系。

从这些环境中分离到得1株土星拟威尔酵母(*Williopsis saturnus*)WC91-2能够分泌嗜杀因子[17]，在医药、食品和农业生产上有重要的用途。

2.3 酵母在海洋沉积物中的分布

在南极浅海沉积物中主要有解脂耶罗威亚酵母(*Yarrowia lipolytica*)(5株)、汉逊德巴利酵母(*Debaryomyces hansenii*)(5株)和斯鲁菲亚红酵母(*Rhodotorula slooffiae*)(3株)，此外还有鲑色锁掷酵母(*Sporidiobolus salmonicolor*)(2株)、木拉克酵母(*Mrakia* sp.)(2株)、小红酵母(*Rhodotorula minuta*)(1株)、胶红酵母(*Rhodotorula mucilaginosa*)(1株)和出芽短梗霉(*Aureobasidium pullulans*)(1株)。在山东沿海的海泥中主要分离到解脂耶罗威亚酵母(*Yarrowia lipolytica*)(2株)、季也蒙毕赤酵母(*Pichia guilliermondii*)(4株)，此外还有白假丝酵母(*Candida albicans*)(1株)、指甲毕赤酵母(*Pichia onychis*)(1株)。

本实验室从南极环境中还分离出两株蛋白含量非常高的菌株，分别为解脂耶罗威亚酵母菌株(*Yarrowia lipolytica*)N3c菌株(42.5%)和解脂耶罗威亚酵母(*Yarrowia lipolytica*)菌株N11b(40.4%)[21]，所以在食品工业方面有重要的用途。

另外还发现从南极环境中分离得到的出芽短梗霉(*Aureobasidium pullulans*)菌株N13d分泌的碱性蛋白酶水解螺旋藻蛋白产生的短肽抗氧化活力最大，为82.8%[16]。同时该菌株产生的淀粉酶，在60 ℃，pH为4.5条件下能生产淀粉酶酶活力单位为10 U/mL，该酶具有同时水解土豆生淀粉α-1,4和α-1,6糖苷键的能力[28]，水解α-1,6糖苷键的能力非常高。因此该酶在发酵工业中有着非常重要的用途。

2.4 酵母菌在海洋鱼类中的分布

从不同海洋环境中得到不同种类的鱼类肠道、鳃和体表，从中分离的酵母菌有：解脂耶罗威亚酵母(*Yarrowia lipolytica*)(68株)、汉逊德巴利酵母(*Debaryomyces hansenii*)(57株)、季也蒙毕赤酵母(*Pichia guilliermondii*)(25株)、热带假丝酵母(*Candida tropicalis*)(23株)、奥默柯达酵母(*Kodamaea ohmer*)(22株)、涎沫假丝酵母(*Candida zeylanoides*)(15株)、酿酒酵母(*Saccharomyces cerevisiae*)(11株)、葡萄有孢汉逊酵母(*Hanseniaspora uvarum*)(11株)、胶红酵母(*Rhodotorula mucilaginosa*)(10株)、少孢酵母(*Saccharomyces exiguus*)(9株)、东方伊萨酵母(*Issatchenkia orientalis*)(7株)、近平滑假丝酵母(*Candida parapsilosis*)(7株)、克鲁弗毕赤酵母(*Pichia kluyveri*)(6株)、异常毕赤酵母(*Pichia anomala*)(5株)、梅林假丝酵母(*Candida milleri*)(5株)、光滑假丝酵母(*Candida glabrata*)(5株)、发酵毕赤酵母(*Pichia fermentans*)(4株)、墨西哥毕赤酵母(*Pichia mexicana*)(3株)、大西洋假丝酵母(*Candida atlantica*)(2株)、链状假丝酵母(*Candida catenulata*)(2株)、纤细假丝酵母(*Candida tenuis*)(2株)、出芽短梗霉(*Aureobasidium pullulans*)(1株)、博伊丁假丝酵母(*Candida boidinii*)(1株)、树干毕赤酵母(*Pichia stipitis*)(1株)等。

从天津大港区的鳜鱼体表和肠道分离到汉逊德巴利酵母(*Debaryomyces hansenii*)(10株)、解脂耶罗威亚

酵母(*Yarrowia lipolytica*)(6株)、胶红酵母(*Rhodotorula mucilaginosa*)(3株)、黑马朗假丝酵母(*Candida haemulonii*)(2株)、大西洋假丝酵母(*Candida atlantica*)(2株)、团假丝酵母(*Candida glaebosa*)(1株)、线黑粉菌(*Filobasidium uniguttulatum*)(1株)、涎沫假丝酵母(*Candida zeylanoides*)(2株)、和酿酒酵母(*Saccharomyces cerevisiae*)(1株)。在山东荣成石岛的鲅鱼体表和肠道中主要分离到解脂耶罗威亚酵母(*Yarrowia lipolytica*)(7株)和假丝酵母(*Candida* sp.)(4株),此外还分离到季也蒙毕赤酵母(*Pichia guilliermondii*)(2株)、酿酒酵母(*Saccharomyces cerevisiae*)(1株)、异常毕赤酵母(*Pichia anomala*)(1株)和克鲁弗毕赤酵母(*Pichia kluyveri*)(1株)。在山东长岛的鲅鱼中分离到解脂耶罗威亚酵母(*Yarrowia lipolytica*)(1株)和葡萄有孢汉逊酵母(*Hanseniaspora uvarum*)(1株)。在东海的鲅鱼中分离到热带假丝酵母(*Candida tropicalis*)和挪威毕赤酵母(*Pichia norvegensis*)。从天津大港区的半滑舌鳎鱼体表和肠道分离到汉逊德巴利酵母(*Debaryomyces hansenii*)(4株)、涎沫假丝酵母(*Candida zeylanoides*)(2株)、解脂耶罗威亚酵母(*Yarrowia lipolytica*)(1株)和纤细假丝酵母(*Candida tenuis*)(1株)。从山东荣成石岛的带鱼消化道中分离到解脂耶罗威亚酵母(*Yarrowia lipolytica*)(2株)、汉逊德巴利酵母(*Debaryomyces hansenii*)(1株)和季也蒙毕赤酵母(*Pichia guilliermondii*)(1株)。从黄海的高眼鲽肠道中分离出解脂耶罗威亚酵母(*Yarrowia lipolytica*)(1株)、季也蒙毕赤酵母(*Pichia guilliermondii*)(1株)和西方伊萨酵母(*Issatchenkia occidentalis*)(1株)。从山东荣成石岛的黄花鱼消化道和鳃中分离到汉逊德巴利酵母(*Debaryomyces hanseni-i*)(3株)、解脂耶罗威亚酵母(*Yarrowia lipolytica*)(2株)、季也蒙毕赤酵母(*Pichia guilliermondii*)(1株)和酿酒酵母(*Saccharomyces cerevisiae*)(1株)。从天津大港区的狼鱼的肠道、皮和鳃中分离到汉逊德巴利酵母(*Debaryomyces hansenii*)(2株)、解脂耶罗威亚酵母(*Yarrowia lipolytica*)(1株)、涎沫假丝酵母(*Candida zeylanoides*)(1株)、嗜油假丝酵母(*Candida oleophila*)(1株)和树干毕赤酵母(*Pichia stipitis*)(1株)。从山东荣成石岛的马面鲀花鱼消化道和鳃中分离到季也蒙毕赤酵母(*Pichia guilliermondii*)(1株)、克鲁弗毕赤酵母(*Pichia kluyveri*)(1株)、墨西哥毕赤酵母(*Pichia mexicana*)(1株)和接合拟威尔酵母(*Zygowilliopsis californica*)(1株)。在天津大港区和山东荣成石岛的矛尾腹鱼的肠道、鳃和皮中分离到东方伊萨酵母(*Issatchenkia orientalis*)(2株)、胶红酵母(*Rhodotorula mucilaginosa*)(2株)、季也蒙毕赤酵母(*Pichia guilliermondii*)(1株)、葡萄有孢汉逊酵母(*Hanseniaspora uvarum*)(1株)和汉逊德巴利酵母(*Debaryomyces hansenii*)(1株)。

从厦门海域的赤缸鱼的肠道和鳃中分离到解脂耶罗威亚酵母(*Yarrowia lipolytica*)(2株)、近平滑假丝酵母(*Candida phangngensis*)(1株)、酒精酵母(*Saccharomyces cerevisiae*)(1株)和斯巴达毕赤酵母(*Pichia spartinae*)(1株)。

从这些环境分离到的酒精酵母菌(*Saecharomyces cerevisiae*)发酵葡萄糖和蔗糖时可以产生体积分数16%的乙醇,所以在酒精发酵工业中这些酵母有重要的用途。

分离到的胶红酵母(*Rhodotorula mucilaginosa*)TJY15a转化葡萄糖和木薯淀粉水解物可以在细胞中累积质量分数52.0%的油脂,生物量可达22.0 g/L以上,所以这些酵母菌在生产生物柴油方面有重要的用途。

从这些鱼肠道分离到的解脂耶罗威亚酵母(*Yarrowia lipolytica*)SWJ-1b蛋白质含量的质量分数在55%以上[30],并且来自于其他微生物的各种多糖水解酶基因、弧菌的溶血素基因、碱性蛋白酶基因、脂酶基因、植酸酶基因可以在这些野生型酵母菌中表达,表达的产物具有生物学活性,说明这些高蛋白的解脂耶罗威亚酵母可以进行遗传改良,以便在更多方面进行应用。

长孢路德酵母(*Lodderomyces elongisporus*)YF12c和皱褶假丝酵母(*Candia rugosa*)W18能够产生植酸酶[18],植酸是各种谷物、粮食、豆类和多油种子中的主要含磷化合物,植酸酶可以催化植酸释放出磷酸盐,所以植酸酶可以组入到各种饲料中,从而减少向环境中含磷化合物的排放,以达到保护环境的目的[31]。

分离到的汉逊德巴利酵母(*Debaryomyces hansenii*)菌株hcx-1、季也蒙毕赤酵母(*Pichia guilliermondii*)菌株GZ1和异常毕赤酵母(*Pichia anomala*)菌株YF07b能够生产嗜杀因子[17]。很多研究表明,有许多具有嗜杀能力的酵母菌以及它们的嗜杀因子在医药、食品、农业和发酵工业生产上有广泛的用途[34-35]。

2.5 远海与深海环境中的酵母菌

日本学者认为,对大洋广泛的研究表明[6],酵母菌的群落是到处存在的,种的分布受到地理因素、水环境因素和生物因素的影响。在子囊菌类的酵母中,耐盐的种汉逊德巴利酵母酵母(*Debaryomyces hansenii*)是在海洋中广泛分布的种,它在其他水环境中也一样分布广泛。在担子菌类的酵母中,有些酵母如隐球酵母菌(*Cryptococcus*),胶红酵母(*Rhodotorula*),掷孢酵母(*Sporobolomyces*)广泛分布于不同的大洋区域。担子

菌类酵母在寡营养的大洋海水中一般占酵母菌总数的主要部分。假丝酵母也经常出现,但在大洋水中比在近岸海水和污染的淡水中出现的频率要小,种类也与这些环境的不同,有些种的假丝酵母似乎只在南极的大洋区域出现,相似的种还有白冬孢酵母(*Leucosporidium* spp.)和小合轴酵母(*Sympodiomyces parvus*),它们被认为是喜冷的种[36]。梅奇酵母(*Metschnikowia* spp.)被认为分布于海水、淡水、无脊椎动物、鱼类和藻类当中。梅奇酵母属的二尖梅奇酵母(*Metschnikowia australis*),二尖梅奇酵母变种(*Metschnikowia bicuspidata* var. *bicuspidata*),柴萨米亚二尖梅奇酵母(*Metschnikowia bicuspidata* var. *chathamia*),克瑞斯梅奇酵母(*Metschnikowia krissii*)和佐贝尔梅奇酵母(*Metschnikowia zobellii*)广泛分布于海洋环境中,并属于同一个单系,而在水环境中偶尔出现的种拉考夫假丝酵母(*Metschnikowia reukaufii*)和美极梅奇酵母(*Metschnikowia pulcherrima*)与它们的关系较远[37]。拉考夫假丝酵母(*Metschnikowia reukaufii*)和美极梅奇酵母(*Metschnikowia pulcherrima*)就像几乎所有其它梅奇酵母种一样通常认为分布于陆地上的花、果实和昆虫当中,海洋种的酵母在进化上属于同一进化分类单元,说明它们是从海洋环境中进化而来的。

在不同海洋环境中广泛分布的种通常被认为是外来的种,尤其是因为许多担子菌类的酵母经常被认为是分布在陆地植物的叶片上的,在海洋中出现可能是因为从叶片冲刷到海洋中[36],担子菌类的酵母中掷孢酵母(*Sporobolomyces*)和布勒弹孢酵母(*Bullera*)属的酵母被认为是典型的叶片栖息的酵母。在远离墨西哥的太平洋水域的酵母菌研究中,掷孢酵母(*Sporobolomyces*)和布勒弹孢酵母(*Bullera*)属的酵母出现频率最高[38],有趣的是这些菌的出现频率随着海水远离海岸距离的增加和海水深度的增加而增加。这些事实说明了担子菌酵母不是从陆地植物叶片冲刷来的,是海洋中本土的菌。

从深海沉积物微生物数量的研究中得知,检测到大量的类似酵母的细胞[39-41],在环太平洋深海环境酵母分布研究中[42-44],分离到大量的酵母。球红冬孢酵母(*Rhodosporidium sphaerocarpum*),土星拟威尔酵母(*Williopsis saturnus*)和光滑假丝酵母(*Candida pseudolambica*)被发现在全部站点中是出现频率最高的种类,但是它们的分布几乎集中于骏河湾和鹿儿岛湾的沉积物中,而汉逊德巴利酵母(*Debaryomyces hansenii*)的分布几乎集中于相模湾和骏河湾的沉积物中,虽然以前它们被认为是海洋中普通的子囊菌类。几乎全部的子囊菌类酵母都来自于沉积物中,只有非发酵克鲁维酵母(*Kluyveromyces nonfermentans*)除外,它在沉积物和底栖无脊椎动物中都很常见,但它们只分布在相模湾和骏河湾中,相反,双倒卵形红冬孢酵母(*Rhodosporidium diobovatum*)和胶红酵母(*Rhodotorula Mucilaginosa*)广泛分布于深海不同的位置。

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Beach Nourishment Process and Engineering Technology

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Abstract: Beach nourishment is an engineering used to widen and stabilize an eroding beach by filling abundant sand with or without supporting structures. It provides a best protection to coast erosion and has been applied in the coast protection widely in the developed countries since the end of the last century, and has been developing rapidly in recent years. Beach nourishment includes investigation, restoration and replenishment stages, which are mutual complementing and interacting. It's necessary to survey the coastal environment sufficiently to make a design before restoration, whereafter, to consider filling locations, components, quantity and sources of sand, and to emphasize the beach profile monitoring continuously and sand filling regularly during the replenishment. In the eroding coast with strong wave, absent sand and bare rock, groyne or jetty and offshore submerged groin engineering are needed to support this nourishment against the waves in order to maintain the filled sand stability.

Key words: beach nourishment summary and process; nourishment technology; groyne; offshore submerged groin

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Distribution and Diversity of Yeasts from Marine Evironment

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Abstract: In recent years, yeast bioresources, distribution and biodiversity in different marine environments have been extensively investigated by our research group. A total of 1 051 yeast strains belonging to 22 genera and 63 species were identified by routine and molecular identification. We found that the yeasts are widely distributed in seawater, sediments, salterns, deep sea, surface of different species of marine algae, different species of marine fish and mangrove ecosystems. It was also found that protease, phytase, inulinase, lipase, cellulase, β-1, 3-glucanase, killer toxin, riboflavin and siderophores can be produced by different yeast strains. Therefore, the yeast strains have many potential applications.

Key words: marine environments; yeasts; distribution; diversity

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在海洋环境中的酵母菌分布与多样性

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