

전통누룩에서 분리한 양조용 곰팡이의 배양 특성 연구

문지영¹ · 백성열¹ · 박혜영² · 노현수³ · 여수환^{1*}

¹농촌진흥청 국립농업과학원 농식품자원부 발효식품과, ²국립식량과학원 중부작물부 수확후이용과,
³경상대학교 생명과학부

Cultural Characteristics of Fungi Strains isolated from Korean *Nuruk*

Ji-Young Mun¹, Seong-Yeol Baek¹, Hye-Young Park², Hyeon-Su Ro³ and Soo-Hwan Yeo^{1*}

¹Fermented Food Science Division, Dept. of Agrofood Resources, National Institute of Agricultural Science, Rural Development Administration, Wanju 55365, Republic of Korea

²Crop Post-Harvest Technology Division, National Institute of Crop Science, Rural Development Administration, Suwon 16613, Republic of Korea

³Dept. of Microbiology and Research Institute of Life Science, Gyeongsang National University, Jinju 52828, Republic of Korea

ABSTRACT

We analyzed the cultural characteristics of isolated brewing fungi for developing fermentation starters. In a previous study, we collected 87 domestic *nuruk*, from which 481 fungi strains were isolated and 11 were selected showing improved productivity. After culturing these 11 fungi strains in several types of media, temperatures, carbon and nitrogen sources, *Rhizopus* sp. grew well in MEA, ME20S, PDA medium while *Aspergillus* sp. grew well in ME20S and YES. Both *Rhizopus* sp. and *Aspergillus* sp. survived well at optimal growth temperatures of 30 and 37°C. *Rhizopus* sp. utilized lactose, glucose and peptone sources while *Aspergillus* sp. utilized glucose, mannose, fructose and yeast extract sources. α-Amylase activity was excellent in *L. ramosa* CN044, *R. oryzae* 82-7(MEB), *R. oryzae* CN174 and *A. oryzae* 58-11(WEB) culture extracts. This study suggests that *R. delemar* 26-4, 58-8 and *A. oryzae* 78-5, 37-7 might be appropriate fungi strains for fermentation starters based on development of large fungi bodies and their good enzyme activities.

Key words : Korean traditional *nuruk*, fungi, cultural characteristics, starter, enzyme activity

서 론

바이오산업 발달과 나고야 의정서 발효로 인해 선진국은 유용 생물자원 확보를 위한 노력과 경쟁이 이루어지고 있다. 특히 생물자원 데이터베이스 구축 및 분석 결과에 따르면 (<http://www.kiet.re.kr>), 세계 생물자원의 가치는 700조원으로 추정되고, 국내 출원된 특허 중 두 번째로 많이 사용되는 국내의 생물자원은 미생물(24%)이며, 생물자원의 80%가 의약품, 식품, 화장품에 사용되고 있었다. 우리나라는 해외 생물자원 의존도가 약 70%로 2014년 10월 나고야 의정서 발효 이후, 국내 바이오업계의 추가 부담금이 연간 136억~639억 원 정도로 추정되고 있다(IIT 2014). 최근 우리나라는 탁·약주 및 과실주 생산을 위해 외국에서 종균을 수입하는데 많은 비용을 지불하고 있으며, 특히 국내 종균 시장의 60%를 일본에서 수입하며, 연간 로열티는 120억 원 정도이다(<https://>

www.bioin.or.kr). 이에 따라 발효종균 및 식품소재의 수입 의존도를 낮추기 위해, 토착 발효 미생물의 자원화를 통한 우수 종균의 자급화 필요성이 제기되고 있다.

최근 공장형 막걸리 제조에 주로 사용되는 종균은 1938년 일본산 종균인 *Aspergillus luchuensis* 입국으로(So MH & Lee JW 1996), 전통누룩으로 빚은 탁주보다 풍부한 향미를 느낄 수 없는 것이 지적되기도 하였다(So MH 1991). 전통누룩으로 빚은 탁주는 발효 중에 다양한 유용 미생물의 영향으로 조화로운 풍미를 느낄 수 있지만, 자연 발효방식이기 때문에 탁주의 주질 관리가 까다로운 면이 있다. 따라서 살균한 전분질 원료에 순수 배양한 종균을 접종하여 이러한 문제점을 개선하는 개량누룩 제조와 이들 누룩의 특성에 관한 연구가 활발히 이루어진 바 있다(So MH 1999; So MH *et al* 1999; Park JH *et al* 2012). 최근에는 전통누룩 및 이를 이용한 탁주의 품질 특성(Woo SM *et al* 2010), 원료(통밀, 밀가루, 통보리)에 따른 누룩 제조와 탁주의 이화학적 특성 연구(Jeong JH *et al* 2015), 품종별, 균주별로 제조한 쌀누룩의 특성 등에

* Corresponding author : Soo-Hwan Yeo, Tel : +82-63-238-3610, Fax : +82-63-238-3843, E-mail : yeobio@korea.kr

관한 연구(Im SY *et al* 2014)가 수행된 바 있다. 하지만 대부분이 누룩의 전분질 원료에 대한 연구들이며, 새로운 유형의 발효제 개발을 위한 토착 발효종균의 특성과 양조적성에 관한 연구는 많지 않은 실정이다.

본 연구에서는 토착 발효종균을 이용한 탁주용 발효제 개발을 위해, 국내 전통누룩에서 분리한 양조용 곰팡이의 배양 최적조건과 효소 활성능을 분석하여 한국형 신개발 발효제의 개발 가능성을 검토하였다.

재료 및 방법

1. 곰팡이 선발

본 연구에 사용한 곰팡이 종균은 농촌진흥청 국립농업과학원 발효식품과에서 보존한 균주를 사용하였다(Yeo SH & Baek SY 2014).

2. 균체 성장능 분석

본 연구진의 선행연구를 통해 최종 선발한 11균주(Table 1)를 대상으로 본 연구에서 다양한 배양조건에 따른 곰팡이 균체 성장능을 조사하였다. 곰팡이용 고체 배지로 PDA(Potato dextrose), MEA (Malt extract), CYA(Czapek yeast extract), CZA(Czapek dox), DG18(Dichloran glycerol), OA(Oatmeal), ME20S(Malt extract sucrose), YES(Yeast extract sucrose)를 사용하였고(Table 2), 배양 온도는 20℃, 25℃, 30℃, 37℃ 및 40℃로 실험하였다. 또한 영양원(탄소원, 질소원)에 따른 곰팡이의 생육특성을 살펴보기 위해, Czapek-dox 한천 배지에 탄소원과 질소원의 종류를 다양하게 첨가하여 사용하였다. 탄

소원은 glucose, fructose, galactose, maltose, sucrose, lactose, mannose, mannitol, sorbitol 및 soluble starch 등 10종을, 질소원은 glycine, lysine, peptone, yeast extract, malt extract, urea, ammonium chloride, ammonium sulfate, ammonium nitrate 및 sodium nitrate 등 10종을 사용하였다. 균체 성장능은 배지 표면에 형성된 균사체 집락의 크기를 Caliper(Digimatic caliper 500-180-30, Mitutoyo Co., Japan)를 사용하여 측정하였다.

3. 배양액의 효소 활성

α -Amylase 활성은 1% 가용성 전분용액 2 mL을 40℃ 항온 수조에서 5분간 예열하고, 곰팡이 배양액을 0.1 mL 첨가한 후, 즉시 반응액을 0.1 mL 취하고 40℃에서 30분간 반응시킨 반응액을 0.1 mL 취하여 각각 요오드 용액 10 mL에 첨가하였다. 이 반응액을 10 mm 비색관을 사용하여 670 nm 파장에서 투과도 T%를 측정 후, 볼게무스가(Wohlgemuth value)에 준한 다음 식으로 효소활성을 계산하였다(Choi YH *et al* 2012).

α -Amylase activity(units/g)=

$$\{12.75 \times (T_{30} - T_0) \div 30\} \times \text{dilution rate}$$

4. 통계처리

실험은 3반복으로 측정하여 결과를 평균±표준편차로 나타내었다. 독립변수(배양 배지, 온도, 영양원)가 종속변수(균체 성장능, 효소활성)에 미치는 영향을 검증하기 위해 이원분산 분석(two-way ANOVA)을 실시하였고, 유의성 비교는 Duncan's multiple range test로 $p < 0.05$ 수준에서 검증하였다. 통계처리는 SPSS 12.0 (SPSS Inc., Chicago, IL)을 이용하였다.

Table 1. List of fungi which were used in this study

Sample No.	Species	Strains	Origin	KACC No.
S1	<i>Lichtheimia ramosa</i>	CN044	Asan-si	-
S2	<i>Rhizopus oryzae</i>	CN105	Seocheon-gun	45714
S3	<i>Rhizopus oryzae</i>	CN174	Gongju-si	46418
S4	<i>Rhizopus delemar</i>	26-4	Goseong-gun	46419
S5	<i>Rhizopus delemar</i>	58-8	Sunsan-si	46422
S6	<i>Rhizopus oryzae</i>	82-7	Gangneung-si	46960
S7	<i>Aspergillus luchuensis</i>	34-1	Andong-si	46420
S8	<i>Aspergillus oryzae</i>	58-11	Gunsan-si	46423
S9	<i>Aspergillus luchuensis</i>	74-5	Hwaseong-si	46958
S10	<i>Aspergillus oryzae</i>	78-5	Seoul	-
S11	<i>Aspergillus oryzae</i>	37-7	Busan	-
ST	<i>Aspergillus oryzae</i>	RIB40	Japan	44967

Table 2. Various culture media used in this study

Medium	Contents
PDA	Potato starch 0.4%, dextrose 2%, agar 1.5%, adjust pH 5.6
MEA	Malt extract 3%, mycological peptone 0.5%, agar 1.5%, adjust pH 5.4
CYA	Yeast extract 0.5%, sucrose 3%, NaNO ₃ 0.3%, K ₂ HPO ₄ 0.1%, KCl 0.05%, MgSO ₄ · 7H ₂ O 0.05%, FeSO ₄ · 7H ₂ O 0.01%, agar 2%, adjust pH 6.0~6.5, 1mL/L TMS (ZnSO ₄ · 7H ₂ O 1%, CuSO ₄ · 5H ₂ O 0.5%)
CZA	Sucrose 3%, NaNO ₃ 0.3%, K ₂ HPO ₄ 0.1%, KCl 0.05%, agar 1.5%, adjust pH 6.0~6.5, 1mL/L TMS (ZnSO ₄ · 7H ₂ O 1%, CuSO ₄ · 5H ₂ O 0.5%)
DG18	Peptone 0.5%, glucose 1%, K ₂ HPO ₄ 0.1%, MgSO ₄ · 7H ₂ O 0.05%, dichloran 0.0002%, agar 1.5%, 110 g of glycerol/500 mL, chloramphenicol
OA	Oatmeal 6%, agar 1.25%, adjust pH 6.0
YES	Yeast extract 2.25%, sucrose 20%, MgSO ₄ · 7H ₂ O 0.05%, agar 2.25%
ME20S	Malt extract 3%, sucrose 20%, mycological peptone 0.5%, agar 1.5%, adjust pH 5.4

결과 및 고찰

1. 배양 온도와 배지에 따른 곰팡이 균체 성장능

다양한 온도 조건에서 배지에 따른 곰팡이 균체 성장능을 조사한 결과는 Table 3~6에 제시하였다.

20℃에서 배지에 따른 곰팡이 균체 성장능을 측정한 결과는 Table 3과 같다. *Rhizopus* 속 곰팡이류는 5~85 mm의 성장범위를 나타내었고, DG18 배지에서 성장정도가 유의적으로 낮았으며($p<0.05$), MEA, PDA, YES 배지에서 대부분이 배양 3일차에 최대 성장능을 보였다. Noh JM 등(2013)의 연구에 따르면 *Rhizopus* 속 곰팡이를 액체 배양하였을 때, PDB 보다 MEB 배지에서 균체량이 유의적으로 많았다. 본 연구

에서는 PDA와 MEA 배지 간의 균체 성장능의 차이가 크지 않았는데, 이는 균체 성장정도가 배지 종류보다 형태의 영향을 더 받는 것으로 생각되어진다. *Aspergillus* 속 곰팡이류는 5~60 mm의 성장범위를 나타내었고, DG18, CZA 배지에서 성장정도가 유의적으로 낮았으며($p<0.05$) ME20S, YES 배지에서 50 mm 내외의 성장을 보였다. 일정량의 sucrose가 첨가된 배지에서는 첨가되지 않은 배지에서보다 높은 균체 성장능을 나타내었는데, 이는 적정 농도의 sucrose는 곰팡이 배양 시 균체 농도를 높인다는 Park 등의 연구 결과와 일치하였다 (Park SH et al 2001). *Lichtheimia ramosa*는 DG18 배지에서 성장능이 유의적으로 낮았고, CYA 배지에서는 최대 성장능 (44.7 mm)을 보였다.

Table 3. Fungi growth upon various culture media at 20℃

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S1 ¹⁾	1	5.7±0.6 ^{a2)}	5.0±0.0 ^a	5.0±0.0 ^a	5.7±0.6 ^a	5.0±0.0 ^a	10.7±1.2 ^a	5.0±0.0 ^a	5.3±0.6 ^a
	2	11.0±0.0 ^b	5.0±0.0 ^a	5.0±0.0 ^a	8.0±1.0 ^b	7.3±0.6 ^c	10.7±3.1 ^a	8.7±0.6 ^b	9.7±0.6 ^b
	3	14.3±0.6 ^b	11.0±2.6 ^a	5.0±0.0 ^a	15.7±0.6 ^d	18.3±0.6 ^d	15.7±0.6 ^b	18.7±1.2 ^d	22.3±0.6 ^c
	4	44.7±1.5 ^d	20.0±3.6 ^b	6.7±0.6 ^{abc}	24.3±1.2 ^e	31.7±1.5 ^e	22.7±3.1 ^c	27.0±1.0 ^e	38.3±2.9 ^d
S2	1	11.7±0.6 ^b	6.3±0.6 ^a	5.0±0.0 ^a	11.3±0.6 ^c	7.3±0.6 ^b	10.7±1.2 ^a	12.7±0.6 ^c	7.7±0.6 ^b
	2	37.7±8.1 ^c	26.0±1.0 ^b	5.0±0.0 ^a	62.3±2.5 ^{gh}	54.0±3.6 ^g	35.7±2.1 ^d	57.0±3.5 ^f	58.7±0.6 ^f
	3	43.0±6.1 ^d	58.7±1.2 ^{cd}	7.3±2.5 ^{abc}	85.0±0.0 ⁱ	85.0±0.0 ^j	68.7±1.2 ^h	85.0±0.0 ^j	85.0±0.0 ⁱ
	4	76.7±5.8 ^{gh}	76.7±14.4 ^e	14.0±6.0 ^d	85.0±0.0 ⁱ	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ⁱ
S3	1	11.3±0.6 ^b	5.0±0.0 ^a	5.0±0.0 ^a	10.0±0.0 ^{bc}	5.7±0.6 ^{ab}	8.3±1.5 ^a	11.3±0.6 ^c	6.0±0.0 ^{ab}
	2	73.3±1.5 ^{fg}	21.7±0.6 ^b	5.0±0.0 ^a	63.7±1.5 ^h	57.3±2.5 ^h	38.0±1.0 ^{de}	64.3±2.9 ⁱ	60.7±1.2 ^g
	3	85.0±0.0 ⁱ	55.0±5.0 ^c	5.7±0.6 ^{ab}	85.0±0.0 ⁱ	85.0±0.0 ^j	58.3±2.9 ^e	85.0±0.0 ^j	85.0±0.0 ⁱ

Table 3. Continued

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S3	4	85.0±0.0 ⁱ	85.0±0.0 ^f	9.3±0.6 ^c	85.0±0.0 ⁱ	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ^j
	1	12.3±0.6 ^b	5.0±0.0 ^a	5.0±0.0 ^a	9.7±0.6 ^{bc}	5.0±0.0 ^a	10.3±0.6 ^a	12.0±1.0 ^c	5.7±0.6 ^a
S4	2	71.3±1.2 ^f	24.0±1.0 ^b	5.0±0.0 ^a	62.3±3.2 ^{gh}	34.3±0.6 ^f	40.7±4.0 ^c	62.0±2.6 ^h	49.0±2.6 ^c
	3	85.0±0.0 ⁱ	62.0±5.2 ^d	5.7±0.6 ^{ab}	85.0±0.0 ⁱ	75.7±1.2 ^j	66.7±4.6 ^h	85.0±0.0 ^j	75.7±1.2 ^h
	4	85.0±0.0 ⁱ	85.0±0.0 ^f	12.0±2.6 ^d	85.0±0.0 ⁱ	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ^j
S5	1	10.0±0.0 ^b	5.7±0.6 ^a	5.0±0.0 ^a	9.0±0.0 ^b	6.3±0.6 ^{ab}	10.3±0.6 ^a	11.7±0.6 ^c	7.0±0.0 ^{ab}
	2	67.0±1.0 ^e	22.3±0.6 ^b	5.0±0.0 ^a	60.0±0.0 ^f	53.3±2.1 ^{gh}	38.0±1.0 ^{de}	65.3±2.9 ⁱ	59.3±0.6 ^f
	3	85.0±0.0 ⁱ	58.0±2.0 ^{cd}	6.3±1.5 ^{ab}	85.0±0.0 ⁱ	85.0±0.0 ^j	54.3±0.6 ^f	85.0±0.0 ^j	85.0±0.0 ^j
	4	85.0±0.0 ⁱ	85.0±0.0 ^f	7.0±1.7 ^{abc}	85.0±0.0 ⁱ	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ^j
S6	1	12.0±0.0 ^b	5.0±0.0 ^a	5.0±0.0 ^a	8.3±0.6 ^b	5.0±0.0 ^{ab}	10.0±0.0 ^a	11.0±0.0 ^c	6.0±1.0 ^a
	2	78.7±2.3 ^h	26.3±2.1 ^b	5.0±0.0 ^a	60.7±3.8 ^{fg}	54.7±1.2 ⁱ	37.7±1.2 ^{de}	59.3±1.2 ^g	63.3±1.5 ^f
	3	85.0±0.0 ⁱ	57.3±7.5 ^{cd}	5.0±0.0 ^a	85.0±0.0 ⁱ	85.0±0.0 ^j	73.0±4.4 ⁱ	85.0±0.0 ^j	85.0±0.0 ^j
	4	85.0±0.0 ⁱ	80.0±0.0 ^{ef}	8.3±0.6 ^{bc}	85.0±0.0 ⁱ	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ^j	85.0±0.0 ^j
S7	3	12.0±0.0 ^b	5.7±0.6 ^a	5.0±0.0 ^a	12.7±0.6 ^b	19.0±0.0 ^{ab}	17.3±1.2 ^c	8.0±1.0 ^a	14.7±0.6 ^{cd}
	5	27.0±0.0 ^f	12.0±0.0 ^c	12.0±0.0 ^c	24.7±0.6 ^{ef}	41.0±1.0 ^{def}	30.0±1.0 ^{hi}	28.0±2.0 ^g	34.7±0.6 ^h
	7	41.7±1.5 ⁱ	18.0±1.7 ^c	19.0±1.0 ^{fg}	34.3±1.5 ^{hi}	60.0±0.0 ^j	37.7±1.2 ^k	38.7±2.9 ⁱ	55.0±1.7 ^l
S8	3	8.0±0.0 ^a	6.3±0.6 ^a	5.0±0.0 ^a	12.0±0.0 ^b	16.0±0.0 ^b	14.3±1.2 ^b	12.0±0.0 ^c	15.7±0.6 ^b
	5	24.3±0.6 ^e	15.0±1.0 ^d	15.7±0.6 ^{de}	23.0±0.0 ^d	34.0±1.0 ^{ef}	24.3±0.6 ^e	23.7±0.6 ^f	35.7±2.1 ^f
	7	33.7±2.1 ^g	22.3±0.6 ^f	25.7±0.6 ^h	33.7±1.2 ^h	50.0±1.0 ^{ij}	31.3±2.3 ⁱ	26.7±0.6 ^g	52.3±2.1 ^{ij}
S9	3	12.0±1.0 ^b	5.7±0.6 ^a	5.0±0.0 ^a	15.0±0.0 ^c	19.3±0.6 ^{ab}	15.0±0.0 ^b	12.3±0.6 ^c	15.0±0.0 ^d
	5	22.7±1.2 ^e	12.0±0.0 ^c	11.3±0.6 ^c	28.0±1.0 ^g	41.0±0.0 ^d	26.7±0.6 ^f	27.3±1.2 ^g	32.3±2.5 ^h
	7	38.0±2.0 ^h	18.0±2.0 ^e	18.0±1.0 ^f	39.3±1.2 ^j	59.7±0.6 ^h	34.7±0.6 ^j	35.7±3.2 ^h	44.3±4.0 ^j
S10	3	13.0±1.7 ^{bc}	11.3±0.6 ^{bc}	5.0±0.0 ^a	10.3±0.6 ^a	11.7±0.6 ^a	12.0±1.0 ^a	9.0±0.0 ^{ab}	12.7±0.6 ^a
	5	27.7±2.1 ^f	21.7±0.6 ^f	7.7±0.6 ^b	23.3±0.6 ^{de}	30.3±0.6 ^{de}	26.3±0.6 ^f	28.3±1.5 ^g	33.3±1.2 ^e
	7	41.7±1.5 ⁱ	30.3±1.2 ^h	15.0±0.0 ^d	34.3±2.1 ^{hi}	50.7±1.2 ^j	37.3±0.6 ^k	39.7±1.2 ⁱ	54.0±1.7 ^j
S11	3	15.0±0.0 ^c	6.3±1.2 ^a	8.0±0.0 ^{ab}	12.3±0.6 ^b	17.7±0.6 ^c	11.7±0.6 ^a	10.3±0.6 ^{bc}	18.3±0.6 ^c
	5	26.7±0.6 ^f	11.0±0.0 ^{bc}	19.3±0.6 ^g	22.3±0.6 ^d	34.3±0.6 ^f	20.7±1.2 ^d	20.0±0.0 ^c	36.3±0.6 ^{fg}
	7	39.0±1.7 ^h	16.7±0.6 ^c	31.7±1.5 ⁱ	33.0±1.0 ^h	49.0±1.7 ⁱ	28.7±1.5 ^{gh}	27.7±0.6 ^g	50.3±0.6 ⁱ
ST	3	17.7±0.6 ^d	10.0±0.0 ^b	6.0±0.0 ^a	14.3±0.6 ^c	18.3±0.6 ^c	18.7±0.6 ^c	15.0±0.0 ^d	19.7±0.6 ^{cd}
	5	28.7±0.6 ^f	18.0±1.0 ^e	16.7±0.6 ^e	25.7±0.6 ^f	35.7±0.6 ^g	27.7±2.1 ^{fg}	26.3±0.6 ^g	40.7±0.6 ^g
	7	38.3±1.5 ^h	26.7±0.6 ^g	24.7±1.5 ^h	35.7±1.2 ⁱ	53.3±1.5 ^k	38.7±1.2 ^k	36.3±0.6 ^h	59.7±1.5 ^k

¹⁾ Symbols : S1; *Lich. ramosa* CN044, S2; *R. oryzae* CN105, S3; *R. oryzae* CN174, S4; *R. delemar* 26-4, S5; *R. delemar* 58-8, S6; *R. oryzae* 82-7, S7; *A. luchuensis* 34-1, S8; *A. oryzae* 58-11, S9; *A. luchuensis* 74-5, S10; *A. oryzae* 78-5, S11; *A. oryzae* 37-7, ST; *A. oryzae* RIB40.

²⁾ Statistical difference is marked with superscripts in a row, $p < 0.05$ by Duncan's multiple range test.

Table 4. Fungi growth upon various culture media at 25°C

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S1 ¹⁾	1	6.3±0.6 ^{a2)}	5.0±0.0 ^a	5.0±0.0 ^a	5.7±0.6 ^a	6.7±0.6 ^a	6.0±1.0 ^a	5.3±0.6 ^a	7.7±2.1 ^a
	2	29.3±1.2 ^d	12.7±2.1 ^d	5.7±0.6 ^a	20.3±0.6 ^b	30.3±0.6 ^d	16.7±0.6 ^{bc}	23.0±1.0 ^b	34.7±0.6 ^e
	3	39.7±0.6 ^e	30.7±2.1 ^e	11.7±1.5 ^{abcd}	41.3±2.3 ^g	57.3±0.6 ^e	26.7±1.5 ^d	45.3±0.6 ^f	63.7±1.5 ^f
	4	85.0±0.0 ⁱ	52.0±1.0 ^g	16.3±1.2 ^{def}	57.0±3.5 ^h	85.0±0.0 ^f	33.0±1.0 ^e	64.0±1.7 ^g	85.0±0.0 ^g
S2	1	23.3±3.8 ^{bc}	11.0±1.0 ^{cd}	5.0±0.0 ^a	25.0±3.5 ^d	25.3±2.5 ^c	18.3±1.5 ^{bc}	32.3±2.5 ^c	28.0±1.7 ^{cd}
	2	55.3±4.5 ^f	55.3±4.0 ^{hi}	9.3±2.1 ^{abc}	85.0±0.0 ⁱ	85.0±0.0 ^f	46.7±2.9 ^f	85.0±0.0 ^h	85.0±0.0 ^g
	3	62.7±3.8 ^g	85.0±0.0 ^j	25.7±5.9 ^g	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
	4	80.7±3.1 ^h	85.0±0.0 ^j	39.0±10.4 ^h	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
S3	1	23.3±0.6 ^{bc}	6.3±0.6 ^{ab}	5.0±0.0 ^a	25.3±0.6 ^d	24.7±0.6 ^b	15.0±1.0 ^b	28.3±1.2 ^c	23.7±1.2 ^c
	2	85.0±0.0 ⁱ	48.3±1.5 ^f	5.0±0.0 ^a	85.0±0.0 ⁱ	85.0±0.0 ^f	56.7±5.8 ^h	85.0±0.0 ^h	85.0±0.0 ^g
	3	85.0±0.0 ⁱ	85.0±0.0 ^j	11.0±1.0 ^{acd}	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
	4	85.0±0.0 ⁱ	85.0±0.0 ^j	14.7±1.2 ^{cde}	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
S4	1	25.3±0.6 ^c	8.3±1.2 ^{bc}	5.0±0.0 ^a	27.7±1.2 ^e	21.3±2.3 ^b	18.7±2.5 ^{bc}	28.3±1.5 ^c	23.7±1.2 ^b
	2	85.0±0.0 ⁱ	54.3±1.2 ^{ghi}	7.7±2.9 ^{ab}	85.0±0.0 ⁱ	85.0±0.0 ^f	70.7±0.6 ^j	85.0±0.0 ^h	85.0±0.0 ^g
	3	85.0±0.0 ⁱ	85.0±0.0 ^j	22.0±4.6 ^{fg}	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
	4	85.0±0.0 ⁱ	85.0±0.0 ^j	38.3±8.1 ^h	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
S5	1	21.3±1.2 ^b	7.7±1.2 ^{ab}	5.0±0.0 ^a	23.0±1.0 ^c	26.7±0.6 ^c	20.0±2.8 ^c	30.3±0.6 ^d	27.0±3.0 ^d
	2	85.0±0.0 ⁱ	52.3±5.9 ^{gh}	6.3±0.6 ^a	85.0±0.0 ⁱ	85.0±0.0 ^f	52.3±6.8 ^g	85.0±0.0 ^h	85.0±0.0 ^g
	3	85.0±0.0 ⁱ	85.0±0.0 ^j	10.0±0.0 ^{abc}	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
	4	85.0±0.0 ⁱ	85.0±0.0 ^j	18.7±2.3 ^{ef}	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
S6	1	23.7±0.6 ^{bc}	6.3±0.6 ^{ab}	5.0±0.0 ^a	31.0±1.0 ^f	25.3±1.5 ^c	16.3±1.5 ^{bc}	28.3±1.5 ^c	28.7±1.2 ^{cd}
	2	85.0±0.0 ⁱ	57.0±2.6 ⁱ	5.3±0.6 ^a	85.0±0.0 ⁱ	85.0±0.0 ^f	66.7±2.9 ^j	85.0±0.0 ^h	85.0±0.0 ^g
	3	85.0±0.0 ⁱ	85.0±0.0 ^j	13.7±4.7 ^{bcd}	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
	4	85.0±0.0 ⁱ	85.0±0.0 ^j	16.7±1.5 ^{def}	85.0±0.0 ⁱ	85.0±0.0 ^f	85.0±0.0 ^k	85.0±0.0 ^h	85.0±0.0 ^g
S7	3	22.7±0.6 ^{ab}	11.3±0.6 ^a	8.0±0.0 ^a	21.7±0.6 ^b	37.7±1.2 ^b	23.3±3.5 ^a	25.7±0.6 ^c	30.3±0.6 ^c
	5	43.3±0.6 ^f	20.3±1.2 ^d	19.7±0.6 ^d	39.3±1.2 ^e	70.0±0.0 ^f	38.3±1.5 ^d	43.0±2.6 ^f	70.0±0.0 ^g
	7	60.0±0.0 ^j	31.7±0.6 ^g	32.3±0.6 ^g	60.0±0.0 ⁱ	70.0±0.0 ^f	55.3±1.2 ⁱ	53.3±3.8 ^{hi}	70.0±0.0 ^g
S8	3	23.0±0.0 ^b	14.0±1.0 ^b	12.3±0.6 ^b	24.7±0.6 ^c	33.0±0.0 ^c	21.7±0.6 ^a	19.7±0.6 ^a	33.0±0.0 ^b
	5	38.3±1.2 ^e	24.7±0.6 ^f	29.0±1.0 ^f	42.3±0.6 ^f	56.7±2.9 ^e	35.0±0.0 ^c	32.3±2.1 ^d	63.0±2.6 ^d
	7	47.3±2.5 ^g	37.0±1.0 ^h	44.7±0.6 ^j	50.0±2.0 ^g	68.0±7.2 ^g	48.3±1.5 ^{fg}	33.0±2.6 ^d	73.0±1.7 ^{fg}
S9	3	21.0±0.0 ^a	11.0±0.0 ^a	8.3±0.6 ^a	21.7±1.2 ^b	39.0±0.0 ^b	21.7±1.2 ^a	22.0±0.0 ^{abc}	31.0±0.6 ^c
	5	44.7±0.6 ^f	22.0±1.0 ^{de}	20.0±0.0 ^d	39.7±0.6 ^e	70.0±0.0 ^f	32.7±0.6 ^{bc}	41.3±1.2 ^{ef}	70.0±0.0 ^g
	7	60.0±0.0 ^j	30.7±0.6 ^g	34.3±0.6 ^{gh}	60.0±0.0 ⁱ	70.0±0.0 ^f	51.0±1.7 ^{gh}	51.7±1.5 ^h	70.0±0.0 ^g
S10	3	21.3±0.6 ^{ab}	17.0±0.0 ^c	6.0±0.0 ^a	22.0±0.0 ^b	25.7±1.2 ^a	21.3±0.6 ^a	21.3±0.6 ^{ab}	28.3±0.6 ^a

Table 4. Continued

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S10	5	43.7±0.6 ^f	31.0±1.0 ^g	19.3±1.2 ^d	38.7±3.2 ^e	58.7±1.5 ^e	40.7±1.2 ^{de}	39.0±1.7 ^e	61.3±2.2 ^d
	7	60.0±0.0 ^j	43.3±2.9 ⁱ	37.3±1.2 ⁱ	60.0±0.0 ⁱ	71.0±1.7 ^g	53.3±3.1 ^{hi}	47.7±5.5 ^g	75.0±0.0 ^g
S11	3	26.0±0.0 ^c	14.3±0.6 ^b	15.7±0.6 ^c	18.3±1.2 ^a	33.0±0.0 ^c	21.3±1.5 ^a	22.3±1.2 ^{abc}	34.3±0.6 ^b
	5	45.0±1.0 ^f	22.3±1.2 ^e	36.0±0.0 ^{hi}	35.3±1.5 ^d	58.0±1.7 ^e	34.7±0.6 ^c	39.3±0.6 ^{ef}	61.7±2.9 ^d
ST	7	57.7±2.5 ⁱ	31.3±0.6 ^g	53.0±2.6 ^j	60.0±0.0 ⁱ	75.0±0.0 ^g	46.7±3.2 ^f	51.7±2.9 ^h	75.0±0.0 ^h
	3	28.7±0.6 ^d	13.7±0.6 ^b	12.7±0.6 ^b	20.7±0.6 ^b	36.3±0.6 ^d	21.0±1.0 ^a	23.7±0.6 ^{bc}	39.7±0.6 ^{bc}
ST	5	50.7±1.2 ^h	26.0±1.0 ^f	25.7±0.6 ^e	37.7±0.6 ^e	65.7±0.6 ^f	31.3±1.2 ^b	39.7±0.6 ^{ef}	70.0±0.0 ^{ef}
	7	60.0±0.0 ^j	36.0±1.0 ^h	38.3±4.7 ⁱ	54.3±0.6 ^h	64.0±0.0 ^f	42.7±2.3 ^e	56.0±1.0 ⁱ	70.0±0.0 ^e

¹⁾ Symbols : S1; *Lich. ramosa* CN044, S2; *R. oryzae* CN105, S3; *R. oryzae* CN174, S4; *R. delemar* 26-4, S5; *R. delemar* 58-8, S6; *R. oryzae* 82-7, S7; *A. luchuensis* 34-1, S8; *A. oryzae* 58-11, S9; *A. luchuensis* 74-5, S10; *A. oryzae* 78-5, S11; *A. oryzae* 37-7, ST; *A. oryzae* RIB40.

²⁾ Statistical difference is marked with superscripts in a row, $p < 0.05$ by Duncan's multiple range test.

25°C에서 배지에 따른 곰팡이 균체 성장능을 측정한 결과는 Table 4와 같다. *Rhizopus* 속 곰팡이류는 20°C 결과와 마찬가지로 5~85 mm의 성장능을 나타내었으며, MEA, ME20S, PDA, YES 배지에서 배양 2일차에 최대 성장능을 보였다. *Aspergillus* 속 곰팡이류는 6~75 mm의 성장범위를 나타내었고, 20°C에서와 마찬가지로 ME20S, YES 배지에서 70 mm 내외의 높은 성장능을 보였다. Park JY & Kim JG(2009)는 *A. parasiticus*를 25°C, PDA 배지에서 15일 간 배양한 결과, 6일째 최대로 성장한 후 집락의 직경이 더 이상 유의적으로 증가

하지 않았다고 보고한 바 있는데, 이는 본 연구와 유사한 결과이다. *L. ramosa*는 CYA, ME20S, YES 배지에서 최대 성장능(85 mm)을 보였고, DG18 배지에서 성장정도가 유의적으로 낮았다($p < 0.05$).

30°C에서 배지에 따른 곰팡이 균체 성장능을 측정한 결과는 Table 5와 같다. *Rhizopus* 속 곰팡이류가 우수한 성장능을 보여 DG18, CZA, OA 배지를 제외한 모든 배지에서 2일차에 최대 증식을 나타내었다. *Aspergillus* 속 곰팡이류는 17~70 mm로 배양 3일차에도 20°C, 28°C보다 성장능이 우수함을

Table 5. Fungi growth upon various culture media at 30°C

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S1 ¹⁾	1	16.0±0.0 ^{a2)}	5.0±0.0 ^a	5.0±0.0 ^a	16.0±2.6 ^a	22.7±0.6 ^a	15.3±2.1 ^a	14.3±1.5 ^a	22.0±0.0 ^a
	2	63.7±0.6 ^d	33.3±0.6 ^e	14.0±1.0 ^{ab}	45.3±1.5 ^b	68.0±1.7 ^f	33.7±1.2 ^b	46.7±2.5 ^b	69.7±2.5 ^g
	3	85.0±0.0 ^e	60.0±0.0 ^g	28.3±1.5 ^{cd}	73.3±5.8 ^g	85.0±0.0 ^g	40.3±1.5 ^{cd}	76.7±2.9 ^f	85.0±0.0 ^h
	4	85.0±0.0 ^e	75.7±1.2 ^h	42.7±1.5 ^{ef}	85.0±0.0 ^h	85.0±0.0 ^g	56.3±1.2 ^e	85.0±0.0 ^g	85.0±0.0 ^h
S2	1	47.3±2.5 ^b	22.0±1.0 ^d	5.3±0.6 ^a	55.3±5.0 ^d	51.0±1.7 ^b	13.0±3.5 ^a	57.3±2.5 ^d	53.3±1.5 ^c
	2	85.0±0.0 ^e	85.0±0.0 ^j	28.0±3.6 ^{cd}	85.0±0.0 ^h	85.0±0.0 ^g	77.3±2.5 ^f	85.0±0.0 ^g	85.0±0.0 ^h
	3	85.0±0.0 ^e	85.0±0.0 ^j	43.0±5.3 ^{ef}	85.0±0.0 ^h	85.0±0.0 ^g	80.0±5.0 ^{fg}	85.0±0.0 ^g	85.0±0.0 ^h
	4	85.0±0.0 ^e	85.0±0.0 ^j	60.3±4.6 ^g	85.0±0.0 ^h	85.0±0.0 ^g	81.7±2.9 ^{gh}	85.0±0.0 ^g	85.0±0.0 ^h
S3	1	57.0±1.0 ^c	14.7±1.5 ^b	5.0±0.0 ^a	64.7±0.6 ^c	59.0±1.7 ^c	41.7±0.6 ^d	55.3±2.1 ^d	65.3±0.6 ^c
	2	85.0±0.0 ^e	79.7±2.5 ⁱ	12.3±2.5 ^{ab}	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
	3	85.0±0.0 ^e	85.0±0.0 ^j	19.7±4.5 ^{bc}	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h

Table 5. Continued

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S3	4	85.0±0.0 ^e	85.0±0.0 ^j	26.3±6.8 ^{cd}	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
	1	64.3±1.2 ^d	17.3±1.5 ^{bc}	7.3±1.5 ^a	68.3±2.3 ^f	47.0±2.6 ^c	38.7±2.3 ^c	64.0±3.6 ^e	55.7±1.5 ^b
S4	2	85.0±0.0 ^e	79.7±4.6 ⁱ	28.3±7.6 ^{cd}	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
	3	85.0±0.0 ^e	85.0±0.0 ^j	49.0±8.5 ^f	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
	4	85.0±0.0 ^e	85.0±0.0 ^j	64.0±12.8 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
S5	1	57.3±1.5 ^c	19.0±2.6 ^c	5.0±0.0 ^a	58.3±3.2 ^d	61.7±2.3 ^{de}	42.3±1.5 ^d	57.3±2.1 ^d	64.0±1.0 ^f
	2	85.0±0.0 ^e	85.0±0.0 ^j	15.0±5.0 ^{ab}	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
	3	85.0±0.0 ^e	85.0±0.0 ^j	34.3±4.0 ^{de}	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
	4	85.0±0.0 ^e	85.0±0.0 ^j	49.7±17.0 ^f	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
S6	1	58.3±2.1 ^c	14.3±2.5 ^b	5.0±0.0 ^a	51.7±0.6 ^c	54.3±0.6 ^d	32.7±0.6 ^b	49.3±2.1 ^c	62.7±3.1 ^d
	2	85.0±0.0 ^e	56.0±3.6 ^f	14.3±0.6 ^{ab}	85.0±0.0 ^h	85.0±0.0 ^g	79.3±1.2 ^{fg}	85.0±0.0 ^g	85.0±0.0 ^h
	3	85.0±0.0 ^e	74.3±4.0 ^h	32.3±3.2 ^d	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
	4	85.0±0.0 ^e	85.0±0.0 ^j	47.3±6.8 ^f	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^g	85.0±0.0 ^h
S7	3	32.7±1.5 ^{ab}	17.7±0.6 ^a	19.0±1.0 ^a	35.7±1.2 ^c	60.7±1.2 ^b	35.3±0.6 ^{ab}	34.7±1.5 ^b	51.3±0.6 ^d
	5	60.7±1.2 ^f	30.0±0.0 ^d	38.3±0.6 ^d	60.3±0.6 ^{hi}	70.0±0.0 ^c	54.3±0.6 ^{ef}	53.3±1.2 ^{ef}	70.0±0.0 ^c
	7	60.0±0.0 ^f	37.3±1.5 ^f	60.0±0.0 ^f	61.7±3.5 ⁱ	70.0±0.0 ^c	61.7±2.1 ^h	55.7±1.2 ^f	70.0±0.0 ^c
S8	3	42.0±2.0 ^d	23.7±0.6 ^b	23.3±3.8 ^{bc}	35.7±0.6 ^c	54.0±1.0 ^c	35.3±1.5 ^{ab}	30.7±0.6 ^a	53.7±1.2 ^b
	5	61.3±1.2 ^f	47.0±2.0 ⁱ	41.3±5.5 ^d	55.3±0.6 ^f	70.0±0.0 ^e	52.3±0.6 ^{de}	41.3±1.2 ^c	70.0±0.0 ^e
	7	62.0±2.0 ^f	48.3±1.5 ⁱ	60.0±0.0 ^f	60.0±3.0 ^{hi}	70.0±0.0 ^e	59.0±5.2 ^{gh}	41.3±3.1 ^c	70.0±0.0 ^e
S9	3	30.0±0.0 ^a	17.0±0.0 ^a	19.7±0.6 ^a	32.7±0.6 ^{ab}	61.3±1.2 ^c	36.3±1.5 ^{ab}	40.0±0.0 ^c	53.3±0.6 ^d
	5	56.3±3.2 ^e	29.7±0.6 ^d	40.0±0.0 ^d	56.0±1.0 ^{fg}	70.0±0.0 ^e	49.7±2.5 ^d	61.3±1.2 ^g	70.0±0.0 ^e
	7	60.0±0.0 ^f	43.7±2.9 ^h	58.3±2.9 ^f	60.0±0.0 ^{hi}	70.0±0.0 ^e	58.7±3.2 ^{gh}	61.3±4.0 ^g	70.0±0.0 ^e
S10	3	34.0±1.0 ^b	26.3±0.6 ^c	18.7±0.6 ^a	31.3±1.2 ^a	50.3±0.6 ^b	38.0±1.0 ^b	31.3±1.2 ^a	50.7±0.6 ^a
	5	56.0±1.7 ^e	39.3±1.2 ^{fg}	41.0±1.0 ^d	45.3±0.6 ^{fg}	70.0±0.0 ^e	52.7±2.1 ^{de}	46.7±3.1 ^d	70.0±0.0 ^e
	7	60.0±0.0 ^f	40.0±0.0 ^g	60.0±0.0 ^f	56.3±1.2 ^e	70.0±0.0 ^e	59.3±1.2 ^{gh}	60.0±0.0 ^g	70.0±0.0 ^e
S11	3	32.7±1.2 ^{ab}	24.0±0.0 ^b	24.7±0.6 ^c	34.7±0.6 ^{bc}	51.3±2.3 ^a	33.7±2.3 ^a	30.3±0.6 ^a	47.7±2.1 ^a
	5	55.3±4.2 ^e	43.0±1.7 ^h	45.7±1.2 ^e	58.7±1.5 ^{gh}	70.0±0.0 ^e	54.0±1.7 ^{ef}	47.0±4.4 ^d	70.0±0.0 ^e
	7	60.0±0.0 ^f	54.0±1.0 ^j	60.0±0.0 ^f	65.0±0.0 ^j	70.0±0.0 ^e	57.0±1.7 ^{fg}	60.0±0.0 ^g	70.0±0.0 ^e
ST	3	38.3±2.1 ^c	18.0±0.0 ^a	20.7±0.6 ^{ab}	39.7±0.6 ^d	58.0±0.0 ^d	35.0±1.0 ^{ab}	35.0±0.0 ^b	57.7±0.6 ^c
	5	30.0±1.0 ^a	66.3±1.2 ^k	41.0±0.0 ^d	62.0±2.6 ⁱ	70.0±0.0 ^e	44.3±1.2 ^c	52.3±0.6 ^e	70.0±0.0 ^e
	7	60.0±0.0 ^f	34.0±2.6 ^e	60.0±0.0 ^f	58.7±1.5 ^{gh}	70.0±0.0 ^e	56.7±2.9 ^{fg}	60.0±0.0 ^g	70.0±0.0 ^e

¹⁾ Symbols : S1; *Lich. ramosa* CN044, S2; *R. oryzae* CN105, S3; *R. oryzae* CN174, S4; *R. delemar* 26-4, S5; *R. delemar* 58-8, S6; *R. oryzae* 82-7, S7; *A. luchuensis* 34-1, S8; *A. oryzae* 58-11, S9; *A. luchuensis* 74-5, S10; *A. oryzae* 78-5, S11; *A. oryzae* 37-7, ST; *A. oryzae* RIB40.

²⁾ Statistical difference is marked with superscripts in a row, $p < 0.05$ by Duncan's multiple range test.

Table 6. Fungi growth upon various culture media at 37°C

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S1 ¹⁾	1	24.7±0.6 ^{a2)}	10.3±0.6 ^{ab}	11.7±0.6 ^{bc}	19.3±2.1 ^a	38.0±0.0 ^a	16.7±2.1 ^b	24.3±1.5 ^a	39.0±1.0 ^a
	2	82.0±1.0 ^a	33.3±1.5 ^d	28.0±2.6 ^{ef}	61.7±7.6 ^{de}	83.7±1.2 ^f	46.0±3.6 ^e	57.3±6.8 ^c	81.0±1.0 ^e
	3	85.0±0.0 ^f	65.7±2.1 ^h	45.0±5.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f	67.7±0.6 ^f	85.0±0.0 ^f	85.0±0.0 ^f
	4	85.0±0.0 ^f	81.7±2.9 ^{kl}	59.3±8.1 ⁱ	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
S2	1	32.0±2.0 ^b	18.0±1.0 ^c	17.0±1.7 ^{cd}	58.3±6.1 ^{cd}	85.0±0.0 ^f	8.3±2.3 ^a	68.0±4.6 ^d	74.3±2.3 ^c
	2	58.0±1.0 ^c	66.7±5.8 ^h	43.3±2.9 ^h	85.0±0.0 ^f	85.0±0.0 ^f	76.3±3.2 ^e	85.0±0.0 ^f	85.0±0.0 ^f
	3	85.0±0.0 ^f	76.3±5.5 ^{ij}	65.3±1.5 ^j	85.0±0.0 ^f	85.0±0.0 ^f	81.7±5.8 ^h	85.0±0.0 ^f	85.0±0.0 ^f
	4	85.0±0.0 ^f	80.7±1.2 ^{kl}	84.3±1.2 ^l	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
S3	1	57.7±2.5 ^c	15.7±0.6 ^c	5.7±1.2 ^{ab}	61.0±1.7 ^{de}	73.0±1.0 ^b	37.3±2.3 ^d	57.3±2.5 ^c	71.7±2.9 ^b
	2	85.0±0.0 ^f	53.7±1.5 ^f	20.7±2.1 ^d	85.0±0.0 ^f	85.0±0.0 ^f	78.0±2.6 ^e	85.0±0.0 ^f	85.0±0.0 ^f
	3	85.0±0.0 ^f	85.0±0.0 ^l	31.3±4.2 ^{fg}	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
	4	85.0±0.0 ^f	85.0±0.0 ^l	45.3±2.5 ^h	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
S4	1	70.7±1.2 ^e	13.7±1.2 ^{bc}	11.0±1.0 ^{abc}	63.0±1.0 ^e	81.0±1.0 ^e	46.7±1.2 ^e	72.7±4.6 ^e	76.7±2.9 ^d
	2	85.0±0.0 ^f	45.3±0.6 ^e	33.3±2.9 ^{fg}	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
	3	85.0±0.0 ^f	68.7±1.2 ^h	53.3±2.3 ^{hi}	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
	4	85.0±0.0 ^f	73.0±3.0 ⁱ	65.3±8.1 ^{jk}	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
S5	1	57.0±2.6 ^c	15.7±2.3 ^c	7.0±1.0 ^{ab}	55.7±2.1 ^c	78.0±2.0 ^d	35.7±1.2 ^{cd}	60.7±0.6 ^c	80.3±1.5 ^e
	2	85.0±0.0 ^f	60.0±3.0 ^e	30.0±1.7 ^f	85.0±0.0 ^f	85.0±0.0 ^f	74.7±0.6 ^e	85.0±0.0 ^f	85.0±0.0 ^f
	3	85.0±0.0 ^f	78.3±2.9 ^{jk}	47.3±4.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
	4	85.0±0.0 ^f	73.3±1.5 ⁱ	66.7±6.7 ^{jk}	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
S6	1	66.0±3.6 ^d	8.3±0.6 ^a	5.0±0.0 ^a	43.3±0.6 ^b	75.7±2.1 ^c	33.7±1.5 ^c	53.7±2.1 ^b	71.7±1.5 ^b
	2	85.0±0.0 ^f	43.3±5.8 ^e	22.3±0.6 ^{de}	85.0±0.0 ^f	85.0±0.0 ^f	74.7±0.6 ^e	85.0±0.0 ^f	85.0±0.0 ^f
	3	85.0±0.0 ^f	85.0±0.0 ^l	37.3±1.5 ^e	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
	4	85.0±0.0 ^f	85.0±0.0 ^l	49.7±3.1 ^{hi}	85.0±0.0 ^f	85.0±0.0 ^f	85.0±0.0 ^h	85.0±0.0 ^f	85.0±0.0 ^f
S7	3	24.0±0.0 ^{ab}	18.0±0.0 ^{abc}	21.3±2.5 ^a	19.3±0.6 ^{ab}	39.0±1.0 ^b	19.7±0.6 ^a	28.0±1.7 ^{de}	54.7±0.6 ^c
	5	33.7±0.6 ^d	19.0±1.0 ^{bcd}	35.3±0.6 ^c	31.0±0.0 ^d	56.7±1.5 ^c	34.0±1.0 ^c	39.3±1.2 ^f	70.0±0.0 ^e
	7	42.3±2.5 ^{fg}	21.0±1.0 ^{cd}	50.7±3.1 ^g	40.7±0.6 ^f	65.3±1.5 ^{fgh}	35.3±1.5 ^c	46.7±3.1 ^h	70.0±0.0 ^e
S8	3	27.3±0.6 ^c	19.3±0.6 ^{bcd}	25.0±0.0 ^b	22.7±1.2 ^{bc}	46.3±0.6 ^c	24.0±1.7 ^{bc}	26.0±0.0 ^{cde}	42.7±2.5 ^b
	5	39.0±1.0 ^e	30.0±0.0 ^{fg}	36.0±1.7 ^e	39.0±1.7 ^{ef}	70.0±0.0 ^{hi}	36.0±1.0 ^e	37.0±1.7 ^f	70.0±0.0 ^e
	7	43.7±1.2 ^{gh}	30.3±0.6 ^{fgh}	60.0±0.0 ⁱ	60.0±0.0 ^h	72.3±2.1 ^{ij}	44.0±6.9 ^{fg}	37.7±1.5 ^f	70.0±0.0 ^e
S9	3	25.0±0.0 ^b	15.3±0.6 ^a	29.3±1.2 ^{cd}	24.3±1.2 ^c	43.3±2.5 ^c	20.0±0.0 ^a	20.7±1.2 ^{ab}	57.3±2.5 ^d
	5	38.3±1.5 ^e	21.3±0.6 ^d	45.0±4.4 ^f	40.0±5.0 ^{ef}	64.0±1.7 ^f	29.7±0.6 ^d	29.3±1.2 ^e	70.0±0.0 ^e
	7	48.0±2.0 ^j	24.3±0.6 ^e	60.0±0.0 ⁱ	56.7±5.8 ^h	67.7±3.1 ^{gh}	41.0±1.7 ^f	38.3±4.9 ^f	70.0±0.0 ^e
S10	3	22.7±0.6 ^a	18.0±1.0 ^{abc}	28.3±0.6 ^{cd}	16.7±0.6 ^a	37.0±1.0 ^b	20.7±0.6 ^{ab}	17.7±1.2 ^a	37.7±0.6 ^a

Table 6. Continued

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S10	5	33.0±1.0 ^d	28.7±1.2 ^f	54.3±1.2 ^h	26.0±1.7 ^c	58.0±1.7 ^c	36.0±0.0 ^e	27.7±1.5 ^{cde}	64.3±1.2 ^f
	7	44.7±0.6 ^{hi}	33.3±2.3 ^h	60.0±0.0 ⁱ	32.3±2.1 ^d	70.0±0.0 ^{hi}	42.3±2.5 ^f	37.0±3.6 ^f	75.0±0.0 ^h
S11	3	24.7±0.6 ^{ab}	20.0±0.0 ^{bcd}	26.7±1.2 ^{bc}	23.0±1.7 ^{bc}	34.0±1.0 ^a	25.0±1.0 ^c	23.7±1.2 ^{bc}	38.7±1.5 ^a
	5	33.3±2.1 ^d	29.3±4.0 ^f	46.3±1.2 ^f	36.3±1.2 ^e	53.3±1.2 ^d	40.7±1.2 ^f	37.3±1.5 ^f	61.7±0.6 ^c
	7	42.3±2.1 ^{fg}	33.0±5.2 ^{gh}	60.0±0.0 ⁱ	50.7±3.1 ^g	67.3±2.5 ^g	46.7±2.9 ^g	44.0±4.0 ^{fgh}	70.7±2.1 ^g
ST	3	29.0±0.0 ^c	17.0±0.0 ^{ab}	30.0±0.0 ^d	23.7±1.2 ^c	44.3±3.8 ^c	20.0±0.0 ^a	24.3±1.2 ^{bcd}	40.0±1.0 ^a
	5	41.3±1.2 ^f	29.3±0.6 ^f	51.3±1.2 ^g	37.7±1.5 ^{ef}	70.0±0.0 ^{hi}	33.0±2.6 ^{de}	40.7±1.2 ^{fg}	66.7±2.9 ^f
	7	46.7±1.2 ^{ij}	41.7±0.6 ⁱ	60.0±0.0 ⁱ	50.0±2.0 ^g	73.3±1.2 ^j	52.0±2.0 ^h	52.3±2.1 ⁱ	66.7±2.9 ^f

¹⁾ Symbols : S1; *Lich. ramosa* CN044, S2; *R. oryzae* CN105, S3; *R. oryzae* CN174, S4; *R. delemar* 26-4, S5; *R. delemar* 58-8, S6; *R. oryzae* 82-7, S7; *A. luchuensis* 34-1, S8; *A. oryzae* 58-11, S9; *A. luchuensis* 74-5, S10; *A. oryzae* 78-5, S11; *A. oryzae* 37-7, ST; *A. oryzae* RIB40.

²⁾ Statistical difference is marked with superscripts in a row, $p < 0.05$ by Duncan's multiple range test.

확인하였다. *L. ramosa*는 CYA, ME20S, YES 배지에서 배양 3일차에 최대 성장을 보였으며, 따라서 배양 4일차에 최대 성장을 보였던 25°C보다 30°C에서 성장능이 더 우수함을 확인하였다. 일반적으로 곰팡이의 최적 생육온도는 28°C 전후로 알려져 있으며(Noh JM *et al* 2013; Park JY & Kim JG 2009), 온도와 배지에 따라 균체 성장이 크게 영향을 받는 것으로 알려져 있다.

37°C에서 배지에 따른 곰팡이 균체 성장능을 측정한 결과는 Table 6과 같다. *Rhizopus* 속 곰팡이류는 30°C의 성장능과

유사한 성장능을 보였고, 특히 20~30°C에서 성장이 느렸던 DG18 배지에서도 45.3~84.3 mm로 최대 성장능을 나타내었다. *Aspergillus* 속 곰팡이류는 *A. oryzae* 78-5가 ME20S 배지에서 75 mm의 최대 성장을 보였으나, 이를 제외한 나머지 곰팡이는 전반적으로 30°C에서보다 성장능이 낮았다.

40°C에서 배지에 따른 곰팡이 균체 성장능을 측정한 결과는 Table 7과 같다. *Rhizopus* 속 곰팡이류는 30°C, 37°C보다 성장이 전반적으로 감소하였고, 25°C보다는 성장이 우수하였다. *Aspergillus* 속 곰팡이류 또한 30°C, 37°C보다 전반적으로 성

Table 7. Fungi growth upon various culture media at 40°C

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S1 ¹⁾	1	25.3±2.5 ^{c2)}	11.0±0.0 ^a	11.0±1.7 ^{ab}	19.3±1.5 ^a	38.7±1.2 ^a	17.3±3.1 ^a	23.7±0.6 ^a	41.7±1.5 ^a
	2	51.7±3.5 ^f	37.3±2.5 ^{ef}	28.0±3.5 ^{cde}	43.0±0.0 ^e	84.3±1.2 ^e	39.3±2.1 ^{cd}	49.3±1.2 ^e	85.0±0.0 ^e
	3	57.3±4.6 ^g	56.3±6.5 ^{hij}	47.3±4.6 ^{ij}	73.3±5.8 ^g	85.0±0.0 ^e	57.0±2.6 ^f	76.3±3.2 ⁱ	85.0±0.0 ^e
	4	85.0±0.0 ^k	85.0±0.0 ^m	57.7±4.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ^e	68.3±6.1 ^g	85.0±0.0 ^j	85.0±0.0 ^e
S2	1	16.7±1.2 ^a	8.7±0.6 ^a	13.3±3.1 ^{ab}	21.7±2.9 ^{ab}	85.0±0.0 ^e	40.0±5.0 ^{cd}	53.3±9.5 ^{ef}	50.3±3.5 ^b
	2	51.0±1.7 ^f	31.0±3.6 ^{cde}	24.0±5.6 ^{cd}	71.7±6.7 ^g	85.0±0.0 ^e	65.0±0.0 ^g	82.3±2.5 ^j	83.3±2.9 ^e
	3	76.3±1.5 ^j	48.3±2.9 ^{gh}	31.3±9.7 ^{def}	85.0±0.0 ⁱ	85.0±0.0 ^e	82.7±4.0 ^h	85.0±0.0 ^j	85.0±0.0 ^e
	4	83.3±2.9 ^k	64.0±5.3 ^{jk}	36.0±11.1 ^{efgh}	85.0±0.0 ⁱ	85.0±0.0 ^e	82.7±4.0 ^h	85.0±0.0 ^j	85.0±0.0 ^e
S3	1	19.0±1.0 ^{ab}	6.3±0.6 ^a	9.3±1.2 ^a	30.0±0.0 ^c	34.0±2.0 ^a	24.3±2.1 ^{ab}	24.0±1.0 ^{ab}	58.3±1.5 ^c
	2	41.0±4.0 ^e	27.0±3.0 ^{bcd}	25.3±2.9 ^{cd}	62.3±4.9 ^f	68.0±9.8 ^d	47.0±2.6 ^{de}	40.3±4.7 ^d	85.0±0.0 ^e
	3	43.0±3.6 ^e	49.0±7.8 ^{ghi}	38.0±3.5 ^{fghi}	78.0±3.5 ^h	70.7±8.1 ^d	47.7±9.0 ^{de}	49.0±3.6 ^e	85.0±0.0 ^e

Table 7. Continued

Sample No.	Day	Fungi growth (mm)							
		CYA	CZA	DG18	MEA	ME20S	OA	PDA	YES
S3	4	52.0±3.5 ^f	74.3±1.5 ^l	44.3±4.5 ^{hij}	75.7±4.0 ^{gh}	85.0±0.0 ^e	53.7±11.8 ^{ef}	58.0±8.2 ^f	85.0±0.0 ^e
S4	1	31.7±0.6 ^d	10.7±0.6 ^a	14.0±1.7 ^{ab}	35.7±1.2 ^d	57.7±0.6 ^c	36.7±0.6 ^c	52.7±2.3 ^e	66.7±0.6 ^d
	2	66.3±2.1 ^h	34.7±0.6 ^{def}	29.7±4.5 ^{def}	85.0±0.0 ⁱ	85.0±0.0 ^e	67.7±6.7 ^g	85.0±0.0 ^j	85.0±0.0 ^e
	3	72.0±2.6 ^{ij}	56.0±8.5 ^{hij}	41.3±7.1 ^{ghij}	85.0±0.0 ⁱ	85.0±0.0 ^e	85.0±0.0 ^h	85.0±0.0 ^j	85.0±0.0 ^e
	4	77.0±2.6 ^j	69.0±7.9 ^{kl}	45.0±8.7 ^{hij}	85.0±0.0 ⁱ	85.0±0.0 ^e	85.0±0.0 ^h	85.0±0.0 ^j	85.0±0.0 ^e
S5	1	23.3±0.6 ^{bc}	5.7±0.6 ^a	6.7±2.1 ^a	40.3±3.8 ^e	56.7±5.5 ^c	27.7±2.5 ^b	30.3±0.6 ^c	66.7±4.5 ^d
	2	58.0±7.8 ^g	25.3±1.5 ^{bc}	19.7±4.0 ^{bc}	85.0±0.0 ⁱ	85.0±0.0 ^e	44.3±1.2 ^{cd}	63.7±1.2 ^g	85.0±0.0 ^e
	3	69.0±3.6 ^{hi}	41.0±6.6 ^{fg}	27.7±6.8 ^{cde}	85.0±0.0 ⁱ	85.0±0.0 ^e	70.0±9.2 ^g	85.0±0.0 ^j	85.0±0.0 ^e
	4	85.0±0.0 ^k	58.3±12.6 ^{ij}	32.3±9.5 ^{defg}	85.0±0.0 ⁱ	85.0±0.0 ^e	83.3±2.9 ^h	85.0±0.0 ^j	85.0±0.0 ^e
S6	1	21.7±0.6 ^{bc}	5.0±0.0 ^a	5.7±0.6 ^a	24.7±0.6 ^b	47.0±1.7 ^b	23.7±1.2 ^{ab}	29.0±0.0 ^{bc}	59.3±0.6 ^c
	2	64.3±1.2 ^h	19.7±2.5 ^b	23.3±2.3 ^{cd}	66.3±1.5 ^f	85.0±0.0 ^e	53.0±1.7 ^{ef}	70.0±2.0 ^h	85.0±0.0 ^e
	3	76.0±1.7 ^j	50.0±4.4 ^{ghi}	36.7±2.9 ^{efgh}	85.0±0.0 ⁱ	85.0±0.0 ^e	66.7±2.9 ^g	85.0±0.0 ^j	85.0±0.0 ^e
	4	85.0±0.0 ^k	68.3±10.4 ^{kl}	51.0±1.7 ^{jk}	85.0±0.0 ⁱ	85.0±0.0 ^e	69.7±2.5 ^g	85.0±0.0 ^j	85.0±0.0 ^e
S7	3	16.0±1.0 ^b	11.0±1.0 ^a	26.3±1.5 ^b	11.7±0.6 ^a	25.7±1.2 ^{ab}	14.3±1.2 ^{bc}	15.3±0.6 ^b	39.7±2.1 ^c
	5	22.3±0.6 ^f	15.7±1.2 ^d	47.3±0.6 ^f	17.0±0.0 ^{cd}	35.7±0.6 ^{de}	23.0±3.0 ^f	21.7±0.6 ^{cd}	69.3±1.2 ^h
	7	26.0±1.0 ⁱ	19.3±0.6 ^{fg}	60.0±0.0 ^h	21.7±1.2 ^f	48.7±1.2 ^g	35.3±0.6 ^h	25.0±0.0 ^e	69.0±1.7 ^h
S8	3	19.0±1.0 ^d	12.0±0.0 ^{ab}	23.3±1.2 ^{ab}	12.0±0.0 ^{ab}	32.7±2.1 ^c	15.7±0.6 ^{cd}	15.7±0.6 ^b	35.0±2.6 ^b
	5	25.3±0.6 ^{hi}	19.0±0.0 ^f	37.0±1.7 ^{cd}	18.3±0.6 ^d	49.0±1.0 ^g	30.7±1.2 ^g	25.3±0.6 ^{ef}	58.3±1.5 ^f
	7	29.3±0.6 ^j	21.3±1.5 ^{hi}	43.3±1.5 ^e	27.7±0.6 ^h	59.3±1.5 ^h	35.7±1.2 ^h	27.3±2.1 ^g	69.7±4.5 ^h
S9	3	16.3±0.6 ^{bc}	12.0±0.0 ^{ab}	23.3±1.2 ^{ab}	13.3±0.6 ^b	27.0±1.7 ^{ab}	13.7±1.2 ^{bc}	15.3±0.6 ^b	42.3±0.6 ^{cd}
	5	20.7±0.6 ^e	17.0±0.0 ^e	40.3±0.6 ^{de}	17.3±0.6 ^{cd}	39.3±0.6 ^f	17.0±2.0 ^d	22.7±1.2 ^d	68.7±1.2 ^h
	7	24.3±0.6 ^{gh}	21.7±0.6 ⁱ	54.3±1.2 ^g	21.0±1.7 ^{ef}	50.0±1.0 ^g	20.3±2.1 ^e	27.0±1.7 ^{fg}	70.3±2.5 ^h
S10	3	11.0±0.0 ^a	13.0±0.0 ^{bc}	21.7±0.6 ^a	11.0±0.0 ^a	25.0±0.0 ^a	13.0±1.0 ^b	13.3±0.6 ^a	27.7±1.5 ^a
	5	18.3±0.6 ^d	21.0±0.0 ^{hi}	40.3±0.6 ^{de}	20.0±1.0 ^e	34.7±0.6 ^{cd}	28.3±1.5 ^g	20.3±1.5 ^c	44.0±1.7 ^d
	7	23.0±0.6 ^{fg}	27.7±1.2 ^j	59.3±1.2 ^h	26.7±0.6 ^{gh}	39.3±1.5 ^f	30.0±0.0 ^g	24.7±2.1 ^e	61.3±2.3 ^{fg}
S11	3	17.7±0.6 ^{cd}	14.0±0.0 ^c	20.3±2.1 ^a	16.0±0.0 ^c	26.0±1.7 ^{ab}	13.3±2.1 ^{bc}	16.3±0.6 ^b	29.7±2.1 ^a
	5	24.7±1.2 ^{hi}	20.3±0.6 ^{gh}	35.0±3.6 ^c	27.0±1.0 ^{gh}	38.3±3.5 ^{ef}	29.7±0.6 ^g	25.3±0.6 ^{ef}	47.7±1.2 ^e
	7	34.0±1.0 ^l	27.0±1.0 ^j	47.3±3.8 ^f	37.3±2.1 ^j	41.0±3.6 ^f	34.7±0.6 ^h	33.0±1.0 ^h	66.7±1.5 ^h
ST	3	18.7±1.2 ^d	11.0±0.0 ^a	22.7±0.6 ^a	16.3±0.6 ^c	28.3±1.2 ^b	10.7±0.6 ^a	15.0±0.0 ^{ab}	28.7±1.5 ^a
	5	26.0±0.0 ⁱ	18.3±0.6 ^f	42.7±2.5 ^e	26.0±0.0 ^g	38.7±1.5 ^f	17.7±1.2 ^d	25.7±0.6 ^{efg}	43.7±2.1 ^d
	7	32.3±2.1 ^k	26.7±0.6 ^j	55.3±4.0 ^g	34.0±1.0 ⁱ	48.7±1.5 ^g	39.3±1.2 ⁱ	32.0±1.0 ^h	62.3±2.5 ^g

¹⁾ Symbols : S1; *Lich. ramosa* CN044, S2; *R. oryzae* CN105, S3; *R. oryzae* CN174, S4; *R. delemar* 26-4, S5; *R. delemar* 58-8, S6; *R. oryzae* 82-7, S7; *A. luchuensis* 34-1, S8; *A. oryzae* 58-11, S9; *A. luchuensis* 74-5, S10; *A. oryzae* 78-5, S11; *A. oryzae* 37-7, ST; *A. oryzae* RIB40.

²⁾ Statistical difference is marked with superscripts in a row, $p < 0.05$ by Duncan's multiple range test.

Table 8. Fungi growth upon various carbon sources at 25°C

Sample No.	Day	Fungi growth (mm, 25°C)									
		Galactose	Glucose	Mannose	Fructose	Lactose	Maltose	Sucrose	Soluble starch	Mannitol	Sorbitol
S1 ¹⁾	1	5.0±0.0 ^{a2)}	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a
	2	13.0±1.0 ^b	14.0±2.0 ^d	16.7±1.7 ^c	5.0±0.0 ^a	8.0±2.0 ^b	9.3±1.2 ^b	14.0±1.7 ^{ab}	13.0±1.0 ^b	8.0±5.2 ^a	16.0±1.0 ^b
	3	24.0±1.7 ^c	31.0±1.7 ^c	29.0±3.2 ^d	17.0±2.6 ^e	19.0±1.0 ^d	25.0±0.0 ^e	22.7±3.2 ^b	25.3±1.5 ^c	27.3±7.5 ^b	31.7±1.5 ^d
	4	35.3±1.5 ^e	46.3±2.1 ^g	41.7±2.5 ^f	36.7±2.9 ^f	36.7±2.9 ^e	45.7±7.5 ^e	39.7±2.5 ^c	40.0±5.0 ^d	47.7±6.0 ^f	46.0±5.3 ^e
S2	1	5.0±0.0 ^a	13.3±2.1 ^{cd}	5.0±0.0 ^a	13.3±1.5 ^d	12.7±2.1 ^c	10.0±0.0 ^b	5.0±0.0 ^a	5.7±0.6 ^a	10.0±0.0 ^a	5.7±0.6 ^a
	2	25.3±4.5 ^c	49.3±1.2 ^h	34.0±3.6 ^e	52.7±3.5 ^g	44.0±1.0 ^g	44.7±2.5 ^e	21.3±1.2 ^b	20.7±12.9 ^{bc}	39.0±1.7 ^{de}	22.3±6.8 ^c
	3	77.7±3.2 ^h	85.0±0.0 ⁱ	85.0±0.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	47.0±13.0 ^{cd}	76.7±14.4 ^f	85.0±0.0 ^h	68.0±6.1 ^g
	4	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	55.3±25.7 ^{de}	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^h
S3	1	5.0±0.0 ^a	10.0±0.0 ^b	5.3±0.6 ^a	8.3±0.6 ^{bc}	10.7±1.2 ^c	9.7±0.6 ^b	14.0±1.0 ^{ab}	14.7±0.6 ^b	9.7±0.6 ^a	14.7±0.6 ^b
	2	15.3±0.6 ^b	40.7±3.8 ^f	27.3±1.2 ^d	37.7±2.5 ^f	40.3±2.5 ^f	42.3±2.5 ^e	47.7±3.2 ^{cd}	44.7±2.5 ^d	36.0±1.0 ^{cd}	52.3±2.5 ^f
	3	54.7±2.5 ^g	85.0±0.0 ⁱ	78.3±7.6 ^j	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	85.0±0.0 ^f	85.0±0.0 ^g	76.3±1.5 ^g	85.0±0.0 ^h
	4	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	85.0±0.0 ^f	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^h
S4	1	7.3±0.6 ^a	10.3±0.6 ^b	11.7±2.8 ^b	8.7±1.5 ^{bc}	8.7±0.6 ^b	8.0±1.7 ^{ab}	16.3±1.2 ^{ab}	17.3±1.5 ^b	8.0±1.7 ^a	17.3±1.5 ^b
	2	50.0±1.0 ^f	51.7±1.5 ^h	72.7±4.9 ⁱ	50.0±3.0 ^g	42.3±0.6 ^g	42.3±2.5 ^e	59.3±1.2 ^e	61.7±1.5 ^e	40.0±0.0 ^e	67.0±0.0 ^g
	3	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	85.0±0.0 ^f	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^h
	4	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	85.0±0.0 ^f	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^h
S5	1	6.0±0.0 ^a	10.0±2.0 ^b	9.0±1.0 ^{ab}	10.7±1.2 ^{cd}	12.3±0.6 ^c	5.3±0.0 ^a	15.0±0.0 ^{ab}	17.0±0.0 ^b	5.3±0.6 ^a	17.0±0.0 ^b
	2	37.3±2.1 ^e	55.7±3.2 ^j	63.3±5.8 ^h	58.3±2.9 ^h	56.7±0.6 ^h	49.3±1.2 ^f	56.0±3.5 ^{de}	62.0±1.0 ^e	34.7±1.5 ^{cd}	65.0±2.0 ^g
	3	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	85.0±0.0 ^f	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^h
	4	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	85.0±0.0 ^f	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^h
S6	1	7.0±0.0 ^a	11.0±1.0 ^{bc}	7.3±1.2 ^{ab}	7.3±0.6 ^{ab}	7.3±1.2 ^b	5.7±1.2 ^a	13.7±1.2 ^{ab}	16.0±1.0 ^b	5.7±1.2 ^a	14.7±1.5 ^b
	2	31.7±2.9 ^d	44.7±2.5 ^g	49.3±3.8 ^g	38.7±2.3 ^f	36.3±3.8 ^e	38.3±1.5 ^d	45.7±5.1 ^{cd}	46.0±1.0 ^d	32.0±2.0 ^{bc}	51.3±3.2 ^f
	3	75.0±1.0 ^h	85.0±0.0 ⁱ	85.0±0.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	85.0±0.0 ^f	85.0±0.0 ^g	78.3±7.6 ^g	85.0±0.0 ^h
	4	82.7±4.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^k	85.0±0.0 ⁱ	85.0±0.0 ⁱ	85.0±0.0 ^g	85.0±0.0 ^f	85.0±0.0 ^g	85.0±0.0 ^h	85.0±0.0 ^h
S7	3	5.0±0.0 ^a	10.3±0.6 ^a	10.0±0.0 ^a	11.3±0.6 ^a	6.0±0.0 ^a	6.3±0.6 ^a	12.0±0.0 ^a	10.3±0.6 ^a	6.3±0.6 ^a	13.0±5.2 ^{ab}
	5	5.0±0.0 ^a	17.3±0.6 ^{bc}	17.7±0.6 ^{bc}	17.0±0.0 ^{bc}	10.3±0.6 ^b	16.7±0.6 ^c	20.7±0.6 ^{bc}	18.7±0.6 ^b	12.0±0.0 ^b	17.0±0.0 ^{bcd}
	7	7.0±0.0 ^a	25.0±0.0 ^d	23.3±0.6 ^{def}	23.7±1.2 ^d	17.7±1.2 ^{ef}	23.0±1.0 ^{de}	27.7±0.6 ^d	27.0±2.6 ^f	19.7±0.6 ^d	24.7±0.6 ^{ef}
S8	3	12.0±0.0 ^b	16.3±0.6 ^b	17.3±0.6 ^b	17.3±0.6 ^c	13.7±1.2 ^c	13.0±0.0 ^b	18.7±1.2 ^b	21.0±0.0 ^{cd}	13.0±0.0 ^b	15.7±4.9 ^{bc}
	5	21.7±1.5 ^c	25.7±1.5 ^d	25.0±3.6 ^f	26.0±0.0 ^e	19.7±1.5 ^g	22.3±0.6 ^d	28.3±3.2 ^d	31.0±1.7 ^g	19.0±1.0 ^d	25.7±2.3 ^f
	7	28.7±2.9 ^g	34.3±0.6 ^f	31.7±1.5 ^g	30.7±1.2 ^g	26.7±1.5 ⁱ	29.0±1.7 ^g	37.0±2.6 ^f	40.7±1.2 ⁱ	23.3±1.5 ^c	35.0±5.0 ^g
S9	3	5.0±0.0 ^a	10.0±0.0 ^a	11.7±0.6 ^a	11.0±0.0 ^a	7.3±0.6 ^a	6.0±0.0 ^a	14.0±0.0 ^a	11.0±0.0 ^a	6.0±0.0 ^a	10.0±0.0 ^a
	5	5.0±0.0 ^a	17.7±0.6 ^{bc}	17.7±0.6 ^{bc}	17.3±0.6 ^c	13.0±1.7 ^c	15.7±0.6 ^c	21.7±0.6 ^{bc}	17.0±0.0 ^b	12.0±0.0 ^b	16.7±0.6 ^{bcd}
	7	6.0±0.0 ^a	24.7±0.6 ^d	24.3±0.6 ^{ef}	23.7±0.6 ^d	19.3±0.6 ^{fg}	22.7±0.6 ^{de}	27.7±3.5 ^d	23.7±1.5 ^c	19.0±1.0 ^d	23.7±1.2 ^{ef}

Table 8. Continued

Sample No.	Day	Fungi growth (mm, 25 °C)									
		Galactose	Glucose	Mannose	Fructose	Lactose	Maltose	Sucrose	Soluble starch	Mannitol	Sorbitol
S10	3	18.0±0.0 ^d	18.0±1.0 ^{bc}	19.7±0.6 ^{bcd}	16.0±0.0 ^b	16.0±0.0 ^{de}	16.3±1.2 ^c	20.7±0.6 ^{bc}	22.3±0.6 ^{de}	16.3±1.2 ^c	20.0±0.0 ^{cde}
	5	33.3±1.2 ^h	32.0±2.0 ^e	37.3±4.2 ^h	28.7±1.2 ^f	28.3±0.6 ⁱ	28.7±1.2 ^g	38.7±1.2 ^f	40.0±1.0 ⁱ	29.0±0.0 ^g	32.7±2.5 ^g
	7	44.3±1.5 ^j	51.3±3.1 ⁱ	50.7±3.2 ^j	44.7±0.6 ⁱ	43.0±2.0 ^j	40.0±1.0 ⁱ	53.0±1.0 ^h	54.3±1.2 ^j	40.3±1.5 ⁱ	44.7±2.5 ^h
S11	3	19.0±0.0 ^d	17.3±0.6 ^{bc}	21.7±0.6 ^{cdef}	17.7±0.6 ^c	14.7±0.6 ^{cd}	15.7±0.6 ^c	22.3±0.6 ^c	23.0±0.0 ^{de}	15.7±0.6 ^c	21.0±0.0 ^{def}
	5	34.0±1.7 ^h	25.3±0.6 ^d	34.0±1.7 ^{gh}	24.3±0.6 ^d	23.7±1.2 ^h	24.0±1.7 ^e	33.3±1.2 ^e	33.7±1.2 ^h	24.7±1.7 ^f	34.3±1.2 ^g
	7	43.7±1.2 ^j	36.3±1.2 ^g	45.3±0.6 ⁱ	35.3±0.6 ^h	35.3±1.2 ^k	33.3±1.2 ^h	43.7±1.2 ^g	46.7±1.5 ^j	35.7±1.2 ^h	44.0±1.7 ^h
ST	3	15.0±0.0 ^c	18.7±1.2 ^c	20.3±0.6 ^{bcd}	17.7±1.2 ^c	14.7±0.6 ^{cd}	15.3±0.6 ^c	20.7±0.6 ^{bc}	19.0±1.7 ^{bc}	15.3±0.6 ^c	21.3±0.6 ^{def}
	5	26.7±1.2 ^f	31.3±1.2 ^e	36.0±1.7 ^h	30.0±0.0 ^g	24.3±0.6 ^h	27.0±0.0 ^f	36.3±3.2 ^f	35.7±1.5 ^h	24.7±0.6 ^f	31.7±1.5 ^g
	7	38.3±1.5 ⁱ	45.7±1.2 ^h	47.3±6.4 ^{ij}	45.0±0.0 ⁱ	32.3±0.6 ^j	41.0±1.0 ⁱ	50.3±0.6 ^h	50.0±2.0 ^k	35.0±0.0 ^h	41.3±5.1 ^h

¹⁾ Symbols : S1; *Lich. ramosa* CN044, S2; *R. oryzae* CN105, S3; *R. oryzae* CN174, S4; *R. delemar* 26-4, S5; *R. delemar* 58-8, S6; *R. oryzae* 82-7, S7; *A. luchuensis* 34-1, S8; *A. oryzae* 58-11, S9; *A. luchuensis* 74-5, S10; *A. oryzae* 78-5, S11; *A. oryzae* 37-7, ST; *A. oryzae* RIB40.

²⁾ Statistical difference is marked with superscripts in a row, $p < 0.05$ by Duncan's multiple range test.

장이 감소하였고, 특히 CZA 배지에서 성장의 둔화가 크게 나타났다.

2. 탄소원에 따른 균체 성장능

탄소원에 따른 균체 성장능을 분석한 결과는 Table 8에 나

타내었다. *Rhizopus* 속 곰팡이류는 탄소원인 glucose, fructose, lactose, maltose가 공급되었을 때, 배양 3일차에 최대 성장능(85 mm)을 보인 반면, *Aspergillus* 속 곰팡이류는 glucose, mannose, fructose, sucrose, soluble starch가 공급되었을 때 높은 성장능을 보였다. 특히 *A. oryzae* 78-5는 54.3 mm에 달하는

Table 9. Fungi growth upon various nitrogen sources at 25 °C

Sample No.	Day	Fungi growth (mm, 25 °C)									
		Sodium nitrate	Ammonium chloride	Ammonium nitrate	Ammonium sulfate	Urea	Glycine	Lysine	Peptone	Malt extract	Yeast extract
S1 ¹⁾	1	5.0±0.0 ²⁾	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a	5.0±0.0 ^a	6.3±0.6 ^a	6.3±0.6 ^a	5.7±0.6 ^a	5.0±0.0 ^a
	2	14.0±2.0 ^d	12.7±2.5 ^b	16.7±1.2 ^{bc}	11.3±1.2 ^{cd}	10.0±0.0 ^a	17.7±0.6 ^b	18.0±3.5 ^b	14.7±0.6 ^b	13.0±1.0 ^b	14.7±0.6 ^b
	3	31.0±1.7 ^e	30.3±5.9 ^c	31.3±1.2 ^d	29.0±1.7 ^c	18.0±1.7 ^b	29.3±1.2 ^c	32.3±2.5 ^d	32.0±1.0 ^c	22.7±1.5 ^c	35.3±0.5 ^e
	4	46.3±2.1 ^g	50.0±2.6 ^d	45.3±3.5 ^c	49.3±2.1 ^f	27.3±2.5 ^{cd}	39.7±1.5 ^d	48.0±3.0 ^e	48.7±1.2 ^f	34.0±1.0 ^f	52.7±1.2 ^f
S2	1	13.3±2.1 ^{cd}	11.3±1.5 ^b	5.3±0.6 ^a	12.7±2.1 ^d	5.0±0.0 ^a	6.0±0.0 ^a	5.7±0.6 ^a	20.0±0.0 ^c	20.3±1.5 ^{de}	14.3±2.5 ^b
	2	49.3±1.2 ^h	53.7±1.2 ^d	47.7±8.4 ^e	62.0±2.0 ^j	6.0±0.0 ^a	7.0±0.0 ^a	46.3±2.1 ^c	65.0±4.4 ^g	62.3±4.0 ^j	64.3±5.1 ^g
	3	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	36.0±9.0 ^e	7.7±0.6 ^a	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j
	4	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	81.7±5.8 ^g	61.0±3.6 ^c	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j
S3	1	10.0±0.0 ^b	10.3±0.6 ^b	15.3±2.3 ^b	8.3±0.6 ^b	5.3±0.6 ^a	5.0±0.0 ^a	19.7±0.6 ^b	21.7±1.5 ^c	13.3±1.5 ^b	21.7±0.6 ^c
	2	40.0±4.6 ^f	58.3±2.9 ^c	72.7±2.3 ^f	51.7±1.5 ^g	25.3±3.8 ^c	5.7±0.6 ^a	70.7±0.6 ^g	74.7±0.6 ^h	44.7±0.6 ^g	71.3±1.2 ^h
	3	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	81.7±5.8 ^g	30.7±9.0 ^c	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j
	4	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	85.0±0.0 ^g	78.7±5.1 ^g	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j

Table 9. Continued

Sample No.	Day	Fungi growth (mm, 25 °C)									
		Sodium nitrate	Ammonium chloride	Ammonium nitrate	Ammonium sulfate	Urea	Glycine	Lysine	Peptone	Malt extract	Yeast extract
S4	1	10.3±0.6 ^b	13.3±1.2 ^b	18.3±1.5 ^{bc}	10.3±0.6 ^c	6.0±0.0 ^a	5.0±0.0 ^a	22.7±1.2 ^c	25.0±0.0 ^d	15.7±1.2 ^{bc}	19.7±1.2 ^c
	2	51.7±1.5 ^h	63.3±2.1 ^f	85.0±0.0 ^h	60.0±0.0 ^h	22.7±3.1 ^{bc}	7.0±0.0 ^a	76.3±1.2 ^h	76.7±1.5 ⁱ	62.7±2.3 ⁱ	72.0±2.1 ^h
	3	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	69.3±4.0 ^f	41.7±2.9 ^d	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j
	4	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	85.0±0.0 ^g	80.0±8.7 ^g	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j
S5	1	10.0±2.0 ^b	13.0±3.5 ^b	19.7±0.6 ^c	11.3±1.2 ^{cd}	6.3±0.6 ^a	5.0±0.0 ^a	22.0±1.7 ^c	24.3±0.6 ^d	17.0±2.6 ^{cd}	24.3±2.1 ^d
	2	55.7±3.2 ⁱ	73.3±7.6 ^g	85.0±0.0 ^h	60.0±0.0 ^h	32.7±3.8 ^{de}	19.7±4.7 ^b	77.3±0.6 ^h	79.3±1.5 ^j	58.7±5.5 ^h	80.0±2.0 ^j
	3	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	79.0±3.6 ^g	69.0±1.7 ^f	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j
	4	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	85.0±0.0 ^g	85.0±0.0 ^g	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j
S6	1	11.0±1.0 ^{bc}	13.3±0.6 ^b	17.3±2.1 ^{bc}	11.7±0.6 ^{cd}	7.7±1.5 ^a	5.3±0.6 ^a	19.0±1.0 ^b	24.7±0.6 ^d	17.7±0.6 ^{cd}	21.7±0.6 ^c
	2	44.7±2.5 ^g	58.3±1.5 ^e	78.3±1.5 ^g	59.0±1.7 ^h	34.7±7.5 ^e	6.3±2.3 ^a	66.7±2.9 ^f	79.7±0.6 ^j	56.7±4.7 ^h	72.0±0.0 ^h
	3	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	81.7±5.8 ^g	56.0±9.6 ^e	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j
	4	85.0±0.0 ^j	85.0±0.0 ^h	85.0±0.0 ^h	85.0±0.0 ^j	85.0±0.0 ^g	82.3±4.6 ^g	85.0±0.0 ^j	85.0±0.0 ^k	85.0±0.0 ^j	85.0±0.0 ^j
S7	3	10.3±0.6 ^a	10.7±0.6 ^a	11.7±0.6 ^a	11.0±1.0 ^a	9.3±0.6 ^a	13.0±0.0 ^a	13.7±0.6 ^a	20.3±0.6 ^a	10.0±0.0 ^a	23.0±1.0 ^b
	5	17.3±0.6 ^{bc}	18.7±0.6 ^{de}	19.3±0.6 ^b	20.0±0.0 ^d	15.0±0.0 ^e	20.7±1.2 ^{bc}	19.0±1.7 ^b	35.3±1.5 ^c	31.3±2.3 ^e	37.0±2.6 ^{cd}
	7	25.0±0.0 ^d	25.0±1.0 ⁱ	27.0±1.0 ^e	28.7±0.6 ^{gh}	23.3±1.2 ^e	24.7±3.8 ^{cd}	23.0±2.6 ^{cd}	54.3±0.6 ^{ef}	49.0±2.6 ⁱ	50.3±0.6 ^f
S8	3	16.3±0.6 ^b	15.3±0.6 ^b	20.0±0.0 ^b	15.7±0.6 ^b	18.3±0.6 ^d	19.0±1.0 ^b	19.7±0.6 ^b	24.0±0.0 ^{ab}	21.0±0.0 ^b	19.0±1.0 ^a
	5	25.7±1.5 ^d	21.3±1.5 ^{figh}	30.7±1.2 ^f	24.0±1.0 ^e	26.7±1.5 ^f	34.0±5.3 ^e	27.0±1.7 ^{ef}	37.0±4.4 ^{cd}	35.0±1.0 ^f	37.0±4.4 ^{cd}
	7	34.3±0.6 ^f	23.0±2.0 ^h	40.0±5.0 ^h	25.3±1.5 ^{ef}	34.0±3.6 ⁱ	45.7±4.0 ^f	37.0±2.6 ^g	53.7±1.5 ^e	48.0±2.0 ^j	56.7±2.9 ^{gh}
S9	3	10.0±0.0 ^a	11.3±1.2 ^a	12.0±0.0 ^a	10.7±1.2 ^a	12.0±0.0 ^b	13.0±0.0 ^a	15.0±0.0 ^a	22.0±1.0 ^a	22.0±1.0 ^{bc}	22.0±0.0 ^{ab}
	5	17.7±0.6 ^{bc}	20.0±0.0 ^{ef}	20.3±0.6 ^{bc}	20.0±0.0 ^d	19.3±1.2 ^d	21.7±0.6 ^{bc}	20.7±1.2 ^{bc}	37.3±2.0 ^{cd}	37.0±2.0 ^f	35.0±1.0 ^c
	7	24.7±0.6 ^d	25.0±0.0 ⁱ	29.3±2.1 ^{ef}	28.7±1.5 ^{gh}	27.7±0.6 ^{fig}	28.7±1.2 ^d	25.3±0.6 ^{de}	57.3±1.2 ^{fg}	43.3±1.2 ^h	53.3±1.5 ^{fg}
S10	3	18.0±1.0 ^{bc}	17.7±0.6 ^{cd}	21.0±0.0 ^{bcd}	17.3±0.6 ^c	19.3±0.6 ^d	23.3±1.5 ^{bc}	19.7±0.6 ^b	23.0±0.0 ^a	23.3±0.6 ^{bc}	22.7±0.6 ^b
	5	32.0±2.0 ^e	20.7±1.2 ^{fg}	36.0±1.7 ^g	26.3±1.2 ^f	34.7±2.5 ⁱ	44.7±5.0 ^f	30.0±0.0 ^f	37.3±4.5 ^{cd}	40.3±0.6 ^g	37.0±1.0 ^{cd}
	7	51.3±3.1 ⁱ	22.3±1.2 ^{gh}	48.3±1.2 ⁱ	29.0±1.0 ^{gh}	49.0±1.0 ^k	60.7±4.0 ^h	45.0±1.0 ^h	58.0±1.7 ^g	55.7±1.2 ^j	62.0±2.0 ^j
S11	3	17.3±0.6 ^{bc}	15.3±0.6 ^b	23.7±0.6 ^d	17.0±0.0 ^{bc}	18.0±1.0 ^d	21.0±0.0 ^{bc}	23.0±0.0 ^{cd}	27.0±1.0 ^b	22.3±0.0 ^{bc}	24.7±0.6 ^b
	5	25.3±0.6 ^d	21.3±1.5 ^{figh}	36.3±0.6 ^g	24.3±0.6 ^e	30.7±1.2 ^h	37.7±2.1 ^e	38.3±2.9 ^g	39.7±2.5 ^d	28.0±2.9 ^d	42.0±1.7 ^e
	7	36.3±1.2 ^g	22.0±1.0 ^{gh}	45.7±3.1 ⁱ	26.0±1.0 ^f	43.3±1.2 ^j	51.7±1.5 ^g	52.3±1.5 ⁱ	59.3±1.2 ^{gh}	45.0±1.5 ^h	60.7±1.2 ⁱ
ST	3	18.7±1.2 ^c	16.3±0.6 ^{bc}	23.0±0.0 ^{cd}	16.3±0.6 ^{bc}	18.3±0.6 ^d	20.0±0.0 ^{bc}	21.7±1.5 ^{bc}	26.7±0.6 ^b	24.0±1.7 ^c	24.0±1.7 ^b
	5	31.3±1.2 ^e	25.7±0.6 ⁱ	38.3±1.5 ^{gh}	28.0±0.0 ^g	29.7±0.6 ^{gh}	35.3±0.6 ^e	28.0±2.0 ^{ef}	39.0±3.5 ^{cd}	28.7±2.9 ^d	39.7±4.6 ^{de}
	7	45.7±1.2 ^h	29.3±1.2 ^j	53.3±0.6 ^j	29.7±1.2 ^h	41.3±1.2 ^j	50.0±0.0 ^g	45.3±4.0 ^h	61.7±2.1 ^h	49.7±0.6 ⁱ	59.7±0.6 ^{hi}

¹⁾ Symbols : S1; *Lich. ramosa* CN044, S2; *R. oryzae* CN105, S3; *R. oryzae* CN174, S4; *R. delemar* 26-4, S5; *R. delemar* 58-8, S6; *R. oryzae* 82-7, S7; *A. luchuensis* 34-1, S8; *A. oryzae* 58-11, S9; *A. luchuensis* 74-5, S10; *A. oryzae* 78-5, S11; *A. oryzae* 37-7, ST; *A. oryzae* RIB40.

²⁾ Statistical difference is marked with superscripts in a row, $p < 0.05$ by Duncan's multiple range test.

최대 성장능을 나타내었다. *L. ramosa*는 glucose, mannitol이 공급되었을 때 성장이 우수하였다. 탄소원에 따라 균체 성장 뿐만 아니라, 배양액의 효소활성도 차이를 보여주는 연구가 수행된 바 있으며(Nam TJ *et al* 1999; Hwang JY *et al* 2009), 주로 lactose와 sucrose가 영향을 미치는 것으로 알려져 있다. 본 연구 결과에서도 이와 유사하게 *Rhizopus* 속 곰팡이류는 lactose가, *Aspergillus* 속 곰팡이류는 sucrose가 공급되었을 때 성장이 우수하였으며, 실험에 사용된 세 균주(*Rhizopus* 속, *Aspergillus* 속, *Lichtheimia* 속) 모두 공통적으로 glucose의 영향을 받았다.

3. 질소원에 따른 균체 성장능

질소원에 따른 균체 성장능을 분석한 결과는 Table 9에 나타내었다. *Rhizopus* 속 곰팡이류는 urea, glycine을 제외한 질소원에서 배양 3일차에 최대 성장(85 mm)을 나타내었고, *Aspergillus* 속 곰팡이류는 peptone, yeast extract가 공급되었을 때 55 mm 내외에 달하는 성장능을 보였다. *L. ramosa*는 yeast extract, ammonium chloride가 포함된 배지에서 50 mm가 넘는 성장능을 보였다. Park SH 등(2001)은 여러 종류의 유기 질소원을 동일한 농도(1%)로 첨가하여 균체 성장을 조사한 결과, yeast extract로 배양하였을 때 다른 유기 질소원보다 균체량이 많았으며, 본 연구 결과에서도 이와 유사하였다.

4. 배양액의 α-amylase 활성

본 연구에 사용한 곰팡이를 5% MEB(Malt extract broth),

WEB(Wheat extract broth) 배지에 각각 배양한 후, 배양액의 α-amylase 활성을 측정하여 그 결과를 Fig. 1에 제시하였다. *Rhizopus*, *Aspergillus* 속 곰팡이는 MEB 배지보다 WEB 배지에서 1.5~32.6배 활성이 더 높았고, *L. ramosa*는 WEB 배지보다 MEB 배지에서 2.8배 활성이 더 높았다. MEB 배지에서는 *Rhizopus* 속 곰팡이가 *Aspergillus* 속보다 효소활성이 비교적 높았으나, WEB 배지에서는 *Aspergillus* 속 곰팡이가 *Rhizopus* 속보다 효소활성이 높게 나타났다. 그 이유는 곰팡이 종류별로 분해 또는 활용하는 전분의 종류가 다르기 때문인 것으로 여겨진다. 표준 균주로 사용한 *A. oryzae* RIB40은 본 연구에서 사용한 공시 균주보다 효소활성이 높았으며(OH DS 2004), 시험 균주 간에는 *R. oryzae* CN174가 WEB 배지에서 활성이 2,880 units/mg으로 가장 높았고, *A. oryzae* 58-11, 74-5가 WEB 배지에서 각각 활성이 2,420 units/mg, 2,073 units/mg으로 높게 나타났다. *L. ramosa*는 MEB 배지에서 2,051 units/mg의 활성을 보였다. Noh JM 등(2013)의 연구에서는 *Aspergillus* 속 곰팡이가 WEB 배지보다 MEB 배지에서 아밀라아제 활성이 비교적 높은 것으로 나타나, 본 연구의 결과와는 차이가 있었다. 이러한 결과를 통해 사용한 균주와 배지에 따라 효소활성이 다르게 나타남을 알 수 있었다. 또한, 곰팡이 균주별로 쌀누룩을 만들어 당화력을 측정된 실험에서는(Huh CK *et al* 2014) *Rhizopus* 속 곰팡이가 *Aspergillus* 속보다 전분 분해력이 높은 것으로 나타났다. 본 연구 결과와 여러 참고문헌을 고찰해 보았을 때, 곰팡이 균주별로 당화력과 활용하는 전분의 종류에 차이가 있어 이를 유전학적으로

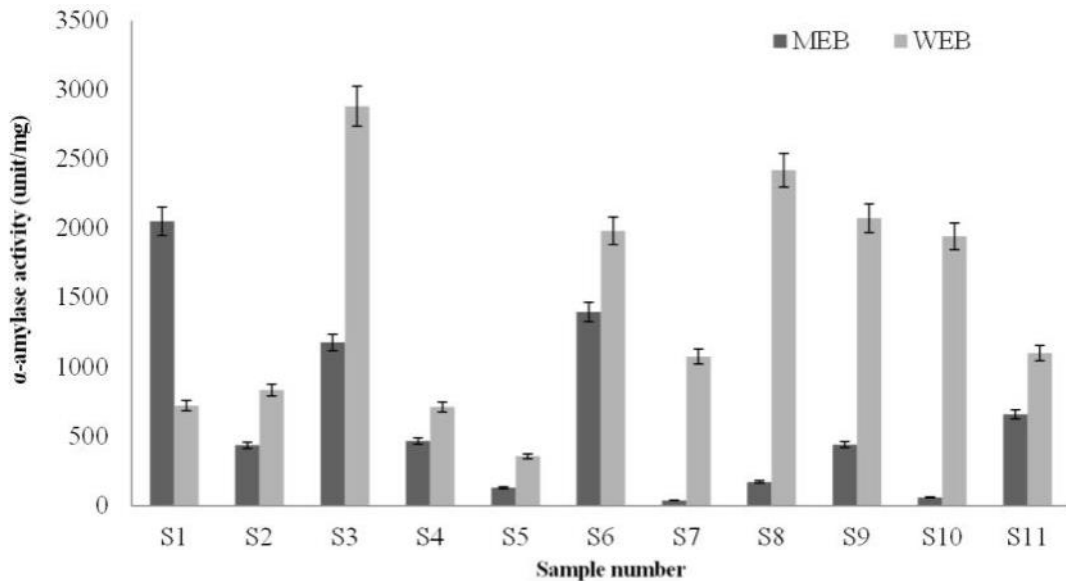


Fig. 1. α-Amylase activity of fungi culture extract upon MEB and WEB. Symbols: S1; *Lich. ramosa* CN044, S2; *R. oryzae* CN105, S3; *R. oryzae* CN174, S4; *R. delemar* 26-4, S5; *R. delemar* 58-8, S6; *R. oryzae* 82-7, S7; *A. luchuensis* 34-1, S8; *A. oryzae* 58-11, S9; *A. luchuensis* 74-5, S10; *A. oryzae* 78-5, S11; *A. oryzae* 37-7, ST; *A. oryzae* RIB40.

일반화하기에는 어려움이 있다고 생각되어진다.

요약 및 결론

Rhizopus 속 곰팡이는 5~85 mm 성장능을 보였으며, 최적 온도 30℃, 37℃ 및 최적 배지 MEA, ME20S, PDA, YES에서 배양 2일차에 최대로 성장하였다. 37℃에서는 다른 배지들보다 성장이 느렸던 DG18 배지에서도 45.3~84.3 mm로 최대 성장을 나타낸 반면, 20℃, 25℃, 40℃에서는 상대적으로 성장이 느리게 나타났다.

Aspergillus 속 곰팡이는 5~75 mm 범위의 성장능을 보였으며, 최적 온도 30℃, 37℃ 및 최적 배지 ME20S, YES에서 배양 5일차에 최대로 성장하였다.

*L. ramosa*는 최적 온도 30℃ 및 최적 배지 CYA, ME20S, YES에서 배양 3일차에 최대로 성장하였으며, DG18 배지에서 성장속도가 유의적으로 낮았다.

영양원에 따른 균체 성장능을 측정된 결과, *Rhizopus* 속 곰팡이는 탄소원인 glucose, fructose, lactose, maltose가, *Aspergillus* 속 곰팡이는 glucose, mannose, fructose, sucrose, soluble starch가, *L. ramosa*는 glucose, mannitol이 공급되었을 때 성장능이 가장 우수하였다. 질소원의 경우 *Rhizopus*, *Aspergillus* 속 곰팡이는 peptone, yeast extract가, *L. ramosa*는 yeast extract, ammonium chloride가 포함된 배지에서 높은 성장능을 보였다.

곰팡이 배양액의 α-amylase 활성은 *R. oryzae* CN174가 WEB 배지에서, *A. oryzae* 58-11, 78-5가 WEB 배지에서 활성이 높게 나타났고, *L. ramosa*는 MEB 배지에서 가장 높은 활성을 보였다.

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