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Selection of *Saccharomyces cerevisiae* Strains Tolerant to Lead and Cadmium Toxicity

Nadia R. A. Nassar, Yehia A. Heikal, Mahmoud A. M. Abou Donia, Mohamed Fadel, Gomaa N. Abdel-Rahman

***Abstract*—**The aim of this study was to select the best strains of *Saccharomyces cerevisiae* able to resist lead and cadmium. Ten strains were screened on the basis of their resistance at different concentrations of 0, 2, 4, 8, 12, 16, 20 and 24 ppm for Pb and 0, 0.5, 1, 2, 4, 6, 8 and 10 ppm for Cd. The properties of baker's yeast quality were decreased by the increase of Pb or Cd in growth medium. The slope values of yield, total viable cells and gassing power of produced baker's yeast were investigated as an indicator of metal resistant. In addition, concentrations of Pb and Cd in produced baker's yeast were determined. The strain of *S. cerevisiae* FH-620 had the highest resistance against Pb and Cd and had the minimum levels of both two investigated metals in produced baker's yeast.

***Keywords*—**Cadmium, lead, *S. cerevisiae*, tolerant.

I. Introduction

BAKER'S yeast (*Saccharomyces cerevisiae*) is one of the oldest products of industrial fermentation that was used traditionally. It is still one of the most important ingredients in industries based on its use for bread-making, a stable food for large section of world's population [1]. Also, baker's yeast is a good source for proteins, essential amino acids, vitamins and also many minerals, i.e., calcium, phosphorous, magnesium and iron [2].

Cane or beet molasses is the primary raw material for bakery yeast production. It supplies all the sugar that yeast needs for growth and energy along with part of the needed nitrogen [3]. Moreover, [4] reported that molasses is used as a raw material for the production of baker's and feed yeast. In addition, [5] studied the metals content of Egyptian cane molasses. He confirmed the presence of copper, lead, cadmium and nickel in cane molasses. The metals concentrations ranged from 7.35 to 22.81 (mean value 12.86 ppm) for copper, from 1.55 to 9.46 (mean value 5.12 ppm) for lead, from 0.14 to 0.82 (mean value 0.40 ppm) for cadmium and from 1.07 to 1.85 (mean value 1.31 ppm) for nickel. Also, [5] reported that the metals concentrations in baker's yeast ranged from 2.38 to 6.49 (mean value 3.82 ppm) for copper, from 0.71 to 2.28 (mean value 1.21 ppm) for lead, from 0.04 to 0.14 (mean value 0.08 ppm) for cadmium and from 0.38 to 0.45 (mean value 0.41 ppm) for nickel.

The heavy metals, such as lead, cadmium and mercury, are non-essential for biological functions, and some heavy metals, such as cadmium and mercury, are strong inhibitors of microbial metabolism, even at low concentrations [6]. The metal toxic effects include the blocking of functional groups, displacement and substitution of essential metal ions from bimolecular, conformational modifications, denaturation and inactivation of enzymes as well as disruption of cellular and organellar membrane integrity [7].

The effect of lead on *S. cerevisiae* was studied by [8]. They reported that addition of 200 μM lead to yeast cell suspension resulted in a decrease of about 15% of the viability in the first 20 min. Baker's yeast is sensitive to high concentrations of lead with an extension of lag phase and duration of the fermentation and an overall decrease in final cell biomass production. Increasing lead concentration resulted in a negative effect on growth rate and maximum dry cell concentration in the aerobic fermentation of molasses [9].

Also, [10] studied the effect of copper concentrations on two wine strains of *Saccharomyces cerevisiae*. The sensitive strain SN9 was strongly affected by copper concentration (32 ppm), whereas the resistant strain SN41 exhibited a good growth activity in presence of 32 ppm of copper. In addition, [11] studied the effect of Pb and Cd on tolerance of *Saccharomyces cerevisiae*. The relative growth rate (% of control) was used to analyze the effect of Pb and Cd at different concentrations on the growth of the yeast cells. They disclosed that the relative growth rate was decreased by increasing Pb or Cd concentrations.

The target of this study is one of the important problems of baker's yeast production in El-Hawmdia for Chemicals Factory, which produces about 45% of the yeast needed for local market. This factory receives different batches of molasses from different locations which differ in their heavy metals content throughout the year. In addition, the gassing power of produced baker's yeast in some batches of molasses was decreased comparing with other batches. Therefore, the present study aimed to evaluate the yield, gassing power and total viable cells of produced baker's yeast of different *Saccharomyces cerevisiae* strains as affected by different concentrations of Pb and Cd to achieve selection of *Saccharomyces cerevisiae* strains that are able to resist the negative effect of these metals.

G. N. Abdel-Rahman is with the Dept. of Food Toxicology and Contaminants, National Res. Center, Dokki, Giza, Egypt (corresponding author to provide phone: +201144248439; fax: 002-33370931; e-mail: Gomma1985@yahoo.com).

N. R. A. Nassar and Y. A. Heikal are with the Food Science Dept., Faculty of Agric., Ain Shams University, Cairo, Egypt.

M. A. M. Abou Donia is with the Dept. of Food Toxicology and Contaminants, National Res. Center, Dokki, Giza, Egypt.

Mohamed Fadel is head of Microbial Chemistry Dept., National Res. Center, Dokki, Giza, Egypt.

II. Materials and Methods

A. Saccharomyces cerevisiae Strains

Yeast strains as describe in Table I were obtained from Microbial Chemistry Dep. collection, National Research Center, Dokki, Giza, Egypt. The yeast strains were maintained in YMP agar slants (0.3% yeast extract, 0.3% malte extract 0.5% peptone and 2% agar) at 4°C. Pre-culturing of *S. cerevisiae* strains was done by activating cells twice as described by [8]. The yeast cells were first transferred to a fresh YMP agar slant and incubated at 30°C for 24 h. Thereafter, a loopful of the cultures were transferred to 250 ml Erlenmeyer flasks containing 50 ml YMPS broth medium (0.3% yeast extract, 0.3 % malte extract 0.5% peptone and 5% sucrose) and incubated for 24 h. at 30°C under shaking condition (150 rpm).

TABLE I
DIFFERENT STRAINS OF *SACCHAROMYCES CEREVISIAE*

No.	Yeast strains	No.	Yeast strains
S_1	S. *cerevisiae* F-707	S_6	S. *cerevisiae* FK-727
S_2	S. *cerevisiae* FA-91	S_7	S. *cerevisiae* FC-620
S_3	S. *cerevisiae* FF-725	S_8	S. *cerevisiae* FH-620
S_4	S. *cerevisiae* F-235	S_9	S. *cerevisiae* FAT-12
S_5	S. *cerevisiae* F-25	S_{10}	S. *cerevisiae* F-514

B. Cultivation

Stock solutions of the studied heavy metal ions were prepared by dissolving cadmium ($CdCl_2$), and lead as Pb $(No_3)_2$ in de-ionized water. Four hundred ml of YMPS cultivation medium were placed in 1l Erlenmeyer flasks, Pb and Cd were added separately to cultivate medium to get final concentrations of 0, 2, 4, 8, 12, 16, 20 and 24 ppm for Pb and 0, 0.5, 1, 2, 4, 6, 8 and 10 ppm for Cd. The flasks were autoclaved for 30 min at 121°C, 16 ml of previously prepared inoculum were used to inoculate each flask. Growth was aerobically carried out at 30°C under shaking condition (150 rpm) for 24 h. At the end of incubation period, yeast yield was recovered by centrifugation at 4500 rpm for 5 min [8].

C. Estimation of Yeast Yield

After centrifugation, yeast cells were washed twice with distilled water and the precipitated layer was weighed [12].

D. Determination of Total Viable Yeast Cells Count

Yeast suspension (1:10) was prepared using saline solution. Samples were then serially diluted and plated on acidic dextrose agar medium (0.3% beef extract, 1% peptone 1% dextrose, 0.5% sodium chloride and 1.5% agar) using pour plate technique according to [12]. The inoculated plates were incubated at 30°C for 2 days. The developing colonies were counted and the total viable yeast counts were expressed as colony forming unit (CFU) per gram of yeast.

E. Evaluation of Gassing Power

Gassing power of baker's yeast was determined using an SJA-Fermentograph NASSJO-Sweden. The analysis was conducted to determine the total carbon dioxide evolved during yeast fermentation in normal dough per one hour. The composition of the prepared dough was 160 ml water, 4g NaC1, 10g (wet weight) of baker's yeast and 280g wheat flour (72%). Mixing of the dough at 35°C for 5min was carried out using a Diosna D-4500 mixer. After mixing, the dough was transferred to a plate and placed in the chamber of the Fermentograph (35°C). The chamber was closed and the recorder was allowed to trace the curve of CO_2 formation for 1 h. The fermentation power was recorded as CO_2 volume after 1 h. [12], [13].

F. Determination of Heavy Metals in Baker's Yeast

A well known weight sample of the obtained yeast (about 2 g) was dried in an oven (105°C). The dried material was ashed in a muffle furnace at 450 - 500°C until the sample was completely combusted (ash turned white / gray or slightly colored). The obtained ash was dissolved using 1 ml concentrated HCl at crucible walls. Dissolved samples were transferred to a 50 ml volumetric flask and de-ionized water was added to complete volume. The solution was filtered through ashless filter paper Whatman No. 42 and stored in a refrigerator until determination by Atomic Absorption Spectrophotometer (PG-990) [5].

G. Statistical Analysis

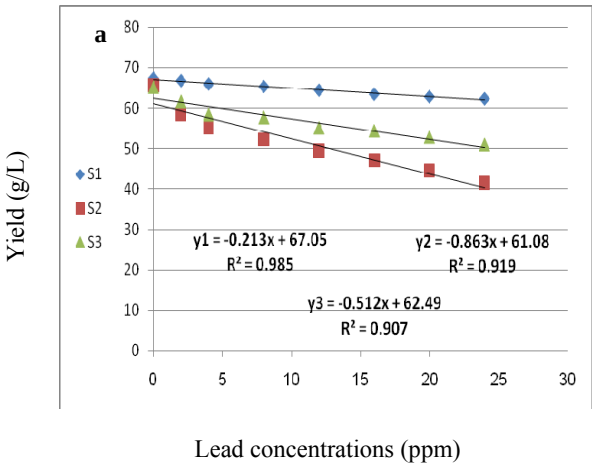
Results were subjected to one-way analysis of variance (ANOVA) of the general liner model (GLM) using SAS statistical package [14]. The results were the average of three experiments ($p \leq 0.05$).

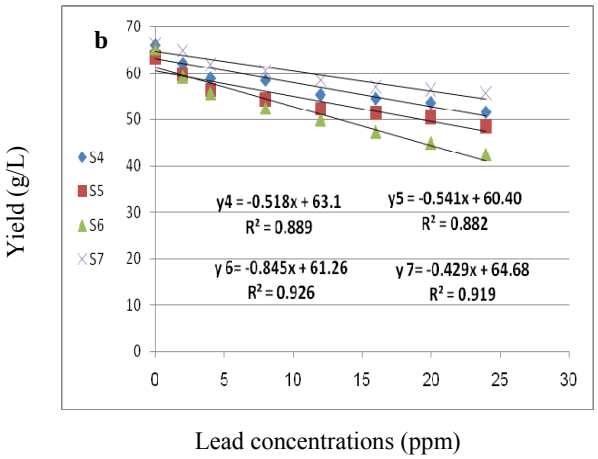
III. RESULTS AND DISCUSSION

The yield, gassing power and total viable cells of different *Saccharomyces cerevisiae* strains after growth at different concentrations of lead (Pb) and cadmium (Cd) are given in Figs. 1-3, respectively for Pb and Figs. 4-6, respectively for Cd. Generally, increasing Pb or Cd concentrations in the growth media decreased the yield, total viable cells and gassing power of all *S. cerevisiae* strains.

A. Effect of Lead

The growth medium was adjusted to Pb concentrations in the range from 0 to 24 ppm. Significant gradual decreases in yield as well as total viable cells and gassing power were observed by increasing the concentration of Pb in the growth medium (Figs. 1-3). The decrease of all parameters under investigation may be due to the high toxicity of Pb, which considered non essential element for baker's yeast growth. The reduction of yeast parameters was variable depending on Pb concentrations and yeast strains.





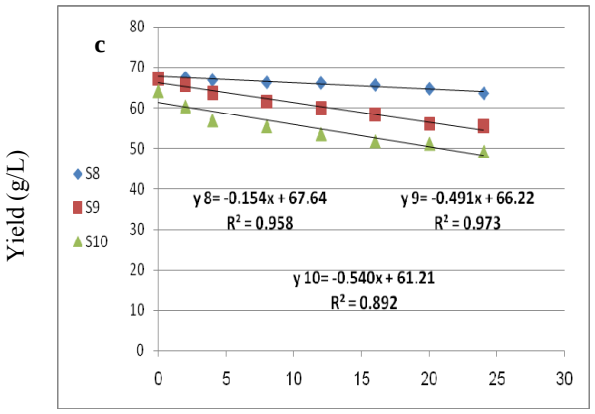
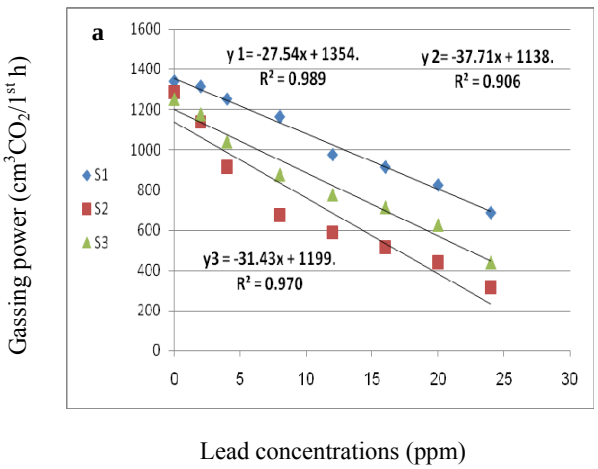
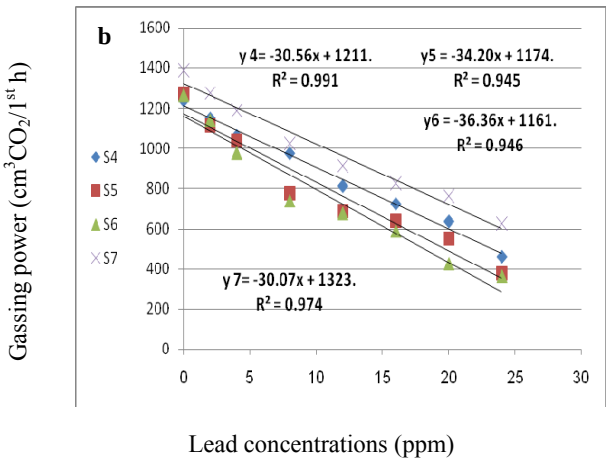


Fig. 1 (a) Effect of lead on yield of *S. cerevisiae* F-707, *S. cerevisiae* FA-91 and *S. cerevisiae* FF-725 strains; (b) Effect of lead on yield of *S. cerevisiae* F-235, *S. cerevisiae* F-25, *S. cerevisiae* FK-727, *S. cerevisiae* FK-727 and *S. cerevisiae* FC-620 strains; (c) Effect of lead on yield of *S. cerevisiae* FH-620, *S. cerevisiae* FAT-12 and *S. cerevisiae F-514* strains





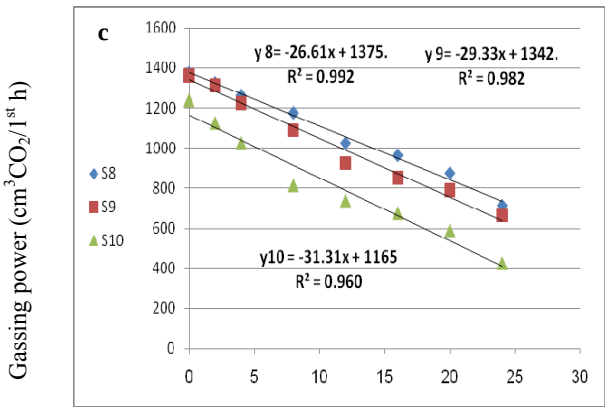


Fig. 2 (a) Effect of lead on gassing power of *S. cerevisiae* F-707, *S. cerevisiae* FA-91 and *S. cerevisiae* FF-725 strains; (b) Effect of lead on gassing power of *S. cerevisiae* F-235, *S. cerevisiae* F-25, *S. cerevisiae* FK-727, *S. cerevisiae* FK-727 and *S. cerevisiae* FC-620 strains; (c) Effect of lead on gassing power of *S. cerevisiae* FH-620, *S. cerevisiae* FAT-12 and *S. cerevisiae F-514* strains

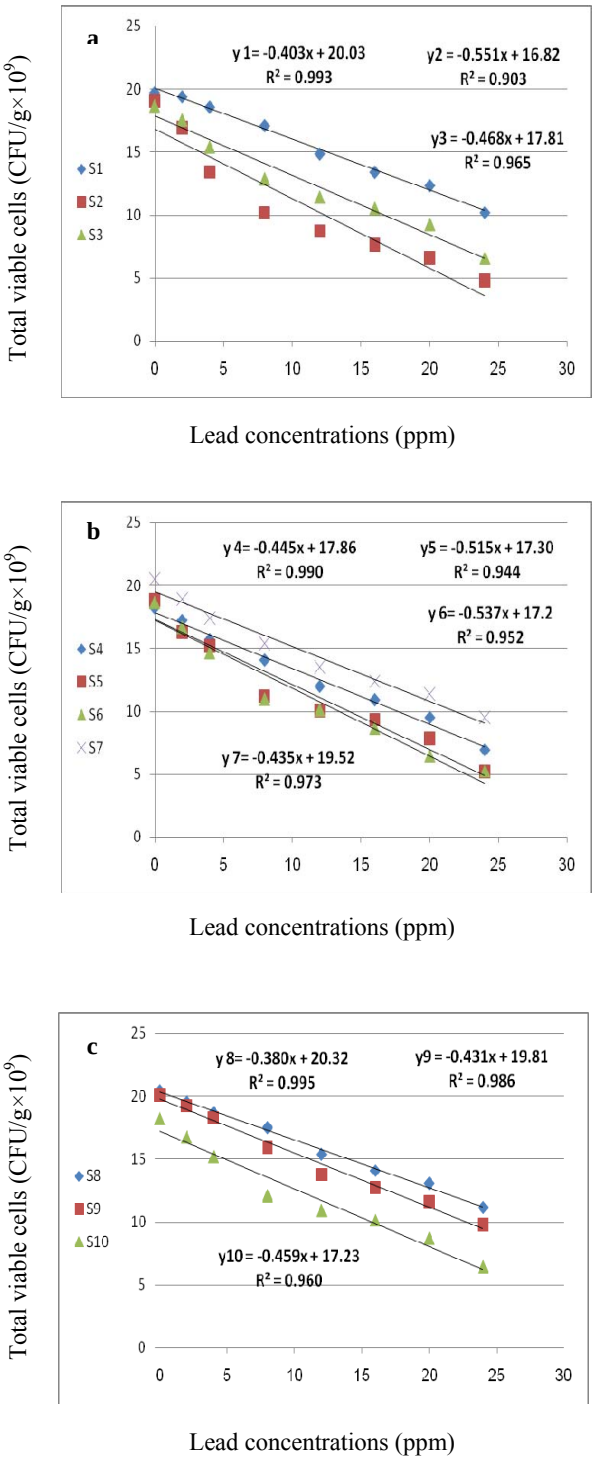


Fig. 3 (a) Effect of lead on total viable cells of *S. cerevisiae* F-707, *S. cerevisiae* FA-91 and *S. cerevisiae* FF-725 strains; (b) Effect of lead on total viable cells of *S. cerevisiae* F-235, *S. cerevisiae* F-25, *S. cerevisiae* FK-727, *S. cerevisiae* FK-727 and *S. cerevisiae* FC-620 strains; (c) Effect of lead on total viable cells of *S. cerevisiae* FH-620, *S. cerevisiae* FAT-12 and *S. cerevisiae F-514* strains

TABLE II
EFFECT OF LEAD ON BAKER'S YEAST PROPERTIES OF S. *CEREVISIAE* STRAINS

No.	Yeast strains	Rate of reduction (Slope)		
		Yield	Gassing power	Total viable cells
S_1	*S. cerevisiae* F-707	- 0.213	- 27.54	- 0.403
S_2	*S. cerevisiae* FA-91	- 0.863	- 37.71	- 0.551
S_3	*S. cerevisiae* FF-725	- 0.512	- 31.43	- 0.468
S_4	*S. cerevisiae* F-235	- 0.518	- 30.56	- 0.445
S_5	*S. cerevisiae* F-25	- 0.541	- 34.20	- 0.515
S_6	*S. cerevisiae* FK-727	- 0.845	- 36.36	- 0.537
S_7	*S. cerevisiae* FC-620	- 0.429	- 30.07	- 0.435
S_8	*S. cerevisiae* FH-620	**- 0.154**	**- 26.61**	**- 0.380**
S_9	*S. cerevisiae* FAT-12	- 0.491	- 29.33	- 0.431
S_{10}	*S. cerevisiae* F-514	- 0.540	- 31.31	- 0.459

Concerning the effect of Pb on yield of different *S. cerevisiae* strains, the results presented in Figs. 1 (a)-(c) and Table II showed that the *S. cerevisiae* FH-620 strain (S_8) had minimum value of slope (-0.154) as an indicator of the high resistant, followed by *S. cerevisiae* F-707 strain (S_1) with a slope value of -0.213, then *S. cerevisiae* FC-620 strain (S_7) with a slope value of -0.429. Meanwhile *S. cerevisiae* FA-91 strain (S_2) recorded the highest value of slope (-0.863) followed by *S. cerevisiae* FK-727 strain (S_6) being -0.845 as an indicator of the low resistant.

Regarding the effect of Pb on gassing power, results in Figs. 2 (a)-(c) and Table II indicate that the *S. cerevisiae* FH-620 strain (S_8) had the lowest value of slope (-26.61) followed by *S. cerevisiae* F-707 strain (S_1) and *S. cerevisiae* FAT-12 strain (S_9) being -27.54 and -29.33, respectively. On the other hand, *S. cerevisiae* FA-91 strain (S_2) and *S. cerevisiae* FK-727 strain (S_6) recorded the highest value of slope being -37.71 and -36.36, respectively. Similar trend was found for total viable cells (Figs. 3 (a)-(c) and Table II), where the lowest values of slope in this respect was recorded for *S. cerevisiae* FH-620 strain (S_8), *S. cerevisiae* F-707 strain (S_1) and *S. cerevisiae* FAT-12 strain (S_9) being -0.380, -0.403 and -0.431, respectively. Meanwhile *S. cerevisiae* FA-91 strain (S_2) recorded the highest value of slope (-0.551) followed by *S. cerevisiae* FK-727 strain (S_6) being -0.537.

These results coincide with those of [8] who revealed that addition of 200µM Pb to yeast cell suspension resulted in a decrease of about 15% of the viability in the first 20min. Baker's yeast is sensitive to any concentrations of Pb with an extension of lag phase and duration of the fermentation and an overall decrease in final cell biomass production. Similar findings were noticed by [11] who indicated that baker's yeast growth was affected by adding Pb (0.0 – 4.0 mmol/L), resulted in a negative effect on growth rate when compared to the control.

B. Effect of Cadmium

Different Cd concentrations ranged between 0 to 10 ppm were tested in order to determine their effect on baker's yeast properties of different *S. cerevisiae* strains (yield, gassing power and total viable cells). Data presented in Figs. 4-6 show a significant gradual decrease in all tested parameters by

increasing Cd concentration in the growth medium. Inhibition was variable depending on Cd concentrations and yeast strains.

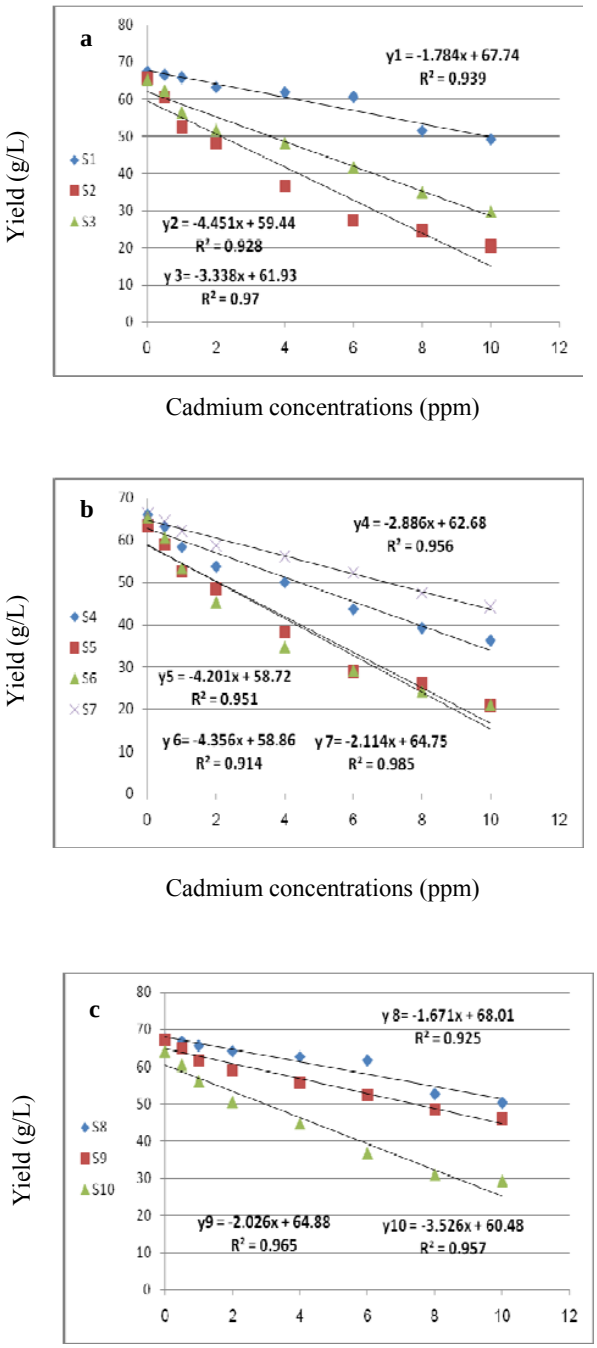


Fig. 4 (a) Effect of cadmium on yield of *S. cerevisiae* F-707, *S. cerevisiae* FA-91 and *S. cerevisiae* FF-725 strains; (b) Effect of cadmium on yield of *S. cerevisiae* F-235, *S. cerevisiae* F-25, *S. cerevisiae* FK-727, *S. cerevisiae* FK-727 and *S. cerevisiae* FC-620 strains; (c) Effect of cadmium on yield of *S. cerevisiae* FH-620, *S. cerevisiae* FAT-12 and *S. cerevisiae F-514* strains

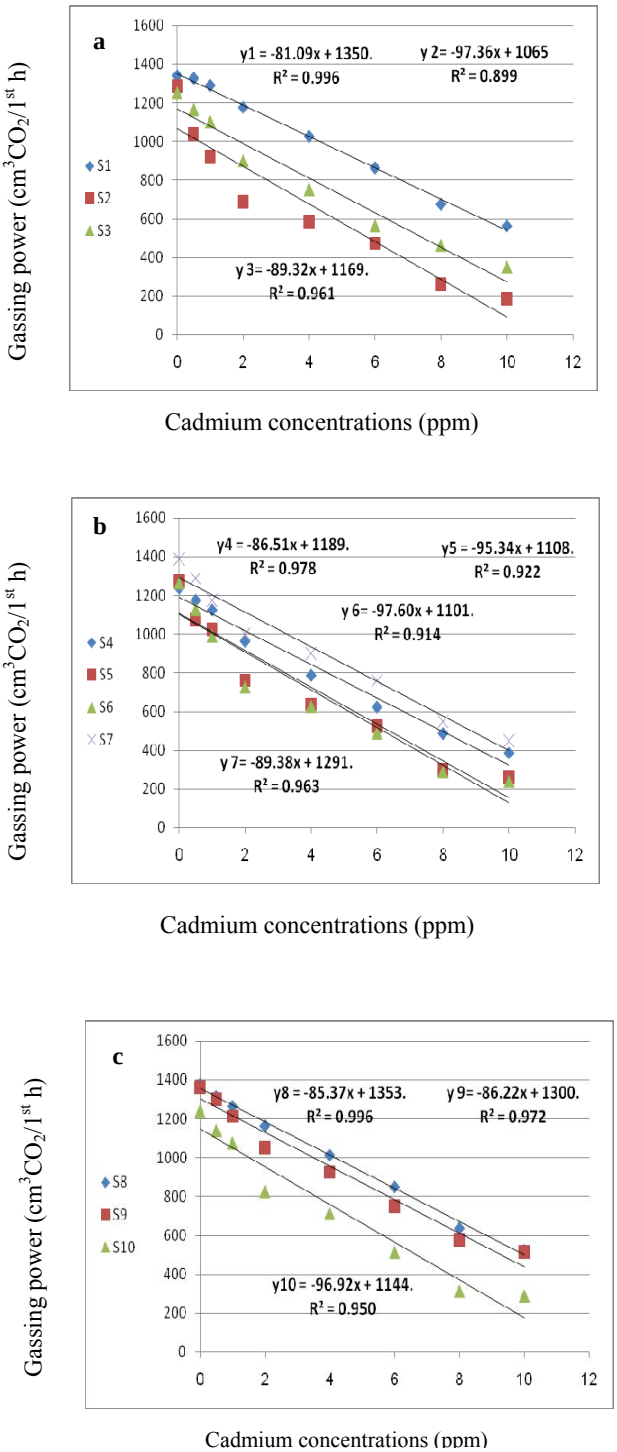


Fig. 5 (a) Effect of cadmium on gassing power of *S. cerevisiae* F-707, *S. cerevisiae* FA-91 and *S. cerevisiae* FF-725 strains; (b) Effect of cadmium on gassing power of *S. cerevisiae* F-235, *S. cerevisiae* F-25, *S. cerevisiae* FK-727, *S. cerevisiae* FK-727 and *S. cerevisiae* FC-620 strains; (c) Effect of cadmium on gassing power of *S. cerevisiae* FH-620, *S. cerevisiae* FAT-12 and *S. cerevisiae F-514* strains

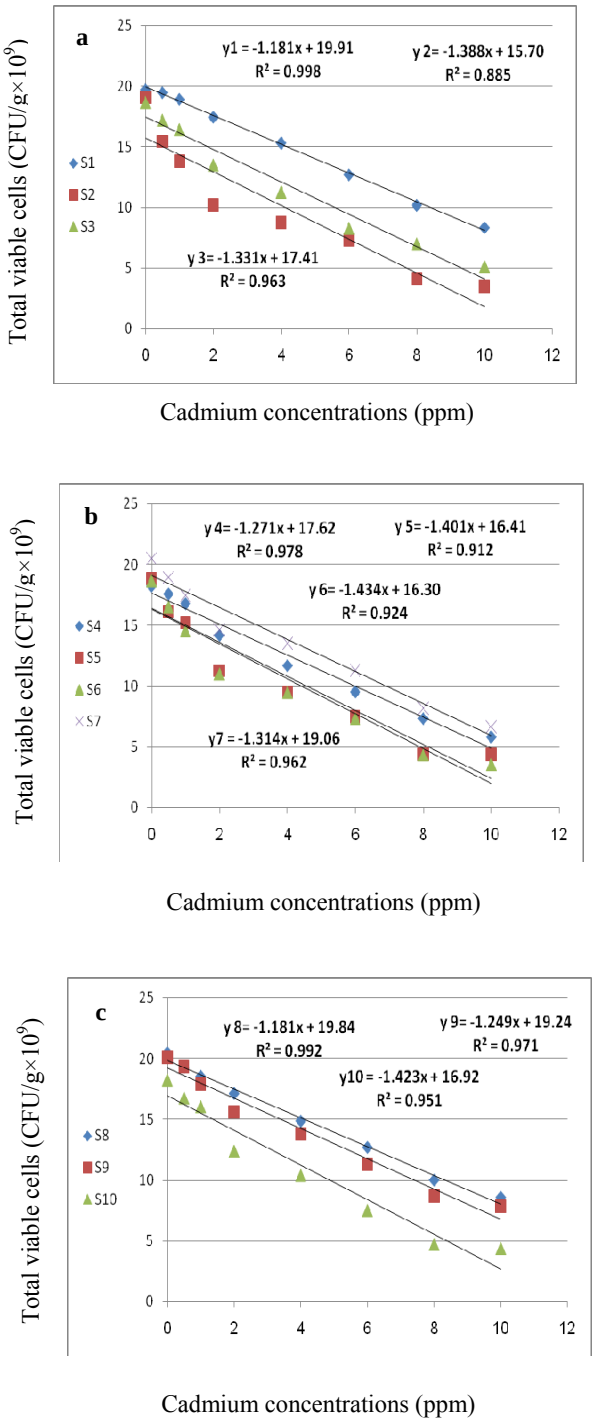


Fig. 6 (a) Effect of cadmium on total viable cells of *S. cerevisiae* F-707, *S. cerevisiae* FA-91 and *S. cerevisiae* FF-725 strains; (b) Effect of cadmium on total viable cells of *S. cerevisiae* F-235, *S. cerevisiae* F-25, *S. cerevisiae* FK-727, *S. cerevisiae* FK-727 and *S. cerevisiae* FC-620 strains; (c) Effect of cadmium on total viable cells of *S. cerevisiae* FH-620, *S. cerevisiae* FAT-12 and *S. cerevisiae F-514* strains

TABLE III
EFFECT OF CADMIUM ON BAKER'S YEAST PROPERTIES OF S. *CEREVISIAE* STRAINS

No.	Yeast strains	RATE OF REDUCTION (SLOPE)		
		Yield	Gassing power	Total viable cells
S_1	*S. cerevisiae* F-707	- 1.784	**- 81.09**	**- 1.181**
S_2	*S. cerevisiae* FA-91	- 4.451	- 97.36	- 1.388
S_3	*S. cerevisiae* FF-725	- 3.338	- 89.32	- 1.331
S_4	*S. cerevisiae* F-235	- 2.886	- 86.51	- 1.271
S_5	*S. cerevisiae* F-25	- 4.201	- 95.34	- 1.401
S_6	*S. cerevisiae* FK-727	- 4.356	- 97.60	- 1.434
S_7	*S. cerevisiae* FC-620	- 2.114	- 89.38	- 1.314
S_8	*S. cerevisiae* FH-620	**- 1.671**	- 85.37	**- 1.181**
S_9	*S. cerevisiae* FAT-12	- 2.026	- 86.22	- 1.249
S_{10}	*S. cerevisiae* F-514	- 3.526	- 96.92	- 1.423

With regard to the effect of Cd on yield of different *S. cerevisiae* strains, the results presented in Figs. 4 (a)-(c) and Table III showed that *S. cerevisiae* FH-620 strain (S_8) was more resistant to Cd followed by *S. cerevisiae* F-707 (S_1) and *S. cerevisiae* FAT-12 (S_9) strains. Where *S. cerevisiae* FH-620 strain (S_8) had lowest value of slope (-1.671), meanwhile, the yield slope of *S. cerevisiae* F-707 (S_1) and *S. cerevisiae* FAT-12 (S_9) strains were -1.784 and -2.026, respectively. On other hand, *S. cerevisiae* FA-91 (S_2) and *S. cerevisiae* FK-727 strains (S_6) were more sensitivity to Cd, where the yield slopes were -4.451 and -4.356, respectively.

Concerning the effect of Cd on gassing power of different *S. cerevisiae* strains, the results presented in Figs. 5 (a)-(c) and Table III appear that the *S. cerevisiae* F-707 strain (S_1) had minimum value of slope (-81.09), followed by *S. cerevisiae* FH-620 strain (S_8) being -85.37, then *S. cerevisiae* FAT-12 strain (S_9) with a slope value of -86.22. Meanwhile, *S. cerevisiae* FK-727 strain (S_6) recorded the highest value of slope (-97.60) followed by *S. cerevisiae* FA-91 strain (S_2), being -97.36.

Results in Figs. 6 (a)-(c) and Table III indicate that a variable inhibition effect of Cd on total viable cells depended on the yeast strains and Cd concentrations in the growth medium. Generally, higher concentrations of metal caused a higher inhibition. Throughout the range of applied Cd concentrations (0 - 10 ppm), the *S. cerevisiae* FH-620 strain (S_8) and *S. cerevisiae* F-707 strain (S_1) had the lowest value of slope for total viable cells being -1.181 followed by *S. cerevisiae* FAT-12 strain (S_9), being -1.249 then *S. cerevisiae* F-235 (S_4) with a slope value of -1.271. Meanwhile *S. cerevisiae* FK-727 strain (S_6) recorded the highest value of slope (-1.434) followed by *S. cerevisiae* F-514 strain (S_{10}), being -1.423.

These results were in agreement with those reported by [11] who found a variable inhibition effect of Cd on *Saccharomyces cerevisiae* depending on the Cd concentrations in the medium. Generally, higher concentrations of metal caused a higher inhibition. In this respect, [15] stated that Cd is nonessential for biological functions and strong inhibitors of yeast metabolism even at low concentrations. Moreover, [16]

reported that Cd strongly binds to functional groups on yeast cell walls. Hence, this result in formation of a Cd-complex with a high formation constant facilitates the displacement of other metals.

Cd toxicity depends on its ability to form complexes with some biological anti-oxidant defense. In support of this hypothesis, a major effect of Cd is to cause oxidative stress, particularly lipid peroxidation [17]. Toxicity of Cd may be also caused by depletion of glutathione (GSH), considered as a major antioxidant in yeast cells [18]. From the results (Figs. 1-6), it could be concluded that *S. cerevisae* strains gave the highest resistance to lead compared with cadmium. Similar findings were noticed by [11] who indicated that, *S. cerevisiae* was sensitive to cadmium but tolerant to copper, zinc, lead, and iron.

C. Determination of Lead and Cadmium in Produced Baker's Yeast

Baker's yeast of different *S. cerevisiae* strains produced on growth medium contained different Pb concentrations were analyzed for its content of Pb and the obtained results are shown in Table IV. The data indicate that the Pb concentrations were gradually increased by increasing Pb concentration in the growth medium from 2 to 24 ppm. A similar trend was reported by [9] who observed that Pb uptake by yeast was increased from 0.6 to 20.4 mg/g by increasing Pb concentration in the growth medium from 3 to 150 ppm.

Cadmium concentrations of produced baker's yeast for different *S. cerevisiae* strains grown on medium contained different Cd concentrations ranged from 0.5 to 10 ppm was investigated and the results are shown in Table V. Data reveal also that the Cd concentrations in yeast biomass were increased by increasing Cd concentrations from 0.5 to 10 ppm. These results are in accordance with those obtained by [19], [20] who reported that the process of Cd uptake by *S. cerevisiae* would be carried out more sufficiently at higher Cd concentrations, the active sites of *S. cerevisiae* would be surrounded by more metal ions. Therefore, the value of Cd uptake increased with increasing of initial Cd ions concentration.

Data in Tables IV, V show also that the highest concentrations of Pb and Cd were achieved for *S. cerevisae* FA-91 strain, followed by *S. cerevisae* FK-727. On other hand, the *S. cerevisiae* FH-620 strain had the lowest values of Pb and Cd followed by *S. cerevisiae* F-707 strain, then *S. cerevisiae* FAT-12 strain. The variation in Pb and Cd concentrations of produced baker's yeast may be due to the differences in the biochemistry of the cell wall, thus motivating differences in the biosorption capacity of the considered strains [21].

TABLE IV
CONCENTRATION OF LEAD IN BAKER'S YEAST OF *SACCHAROMYCES CEREVISAE* STRAINS

Yeast strains	Lead concentration (ppm)						
	2	4	8	12	16	20	24
S. *cerevisiae* F-707	0.15 ^{g} ±0.01	0.37 ^{e} ±0.01	0.95 ^{g} ±0.04	1.56 ^{f} ±0.04	2.07 ^{g} ±0.05	2.92 ^{e} ±0.03	3.50 ^{f} ±0.02
S. *cerevisiae* FA-91	0.61 ^{a} ±0.02	1.21 ^{a} ±0.03	2.31 ^{a} ±0.03	3.68 ^{a} ±0.07	4.52 ^{a} ±0.05	5.53 ^{a} ±0.10	6.61 ^{a} ±0.08
S. *cerevisiae* FF-725	0.32 ^{d} ±0.01	0.65 ^{c} ±0.02	1.46 ^{d} ±0.03	2.37 ^{d} ±0.05	3.10 ^{d} ±0.05	3.93 ^{c} ±0.06	4.54 ^{d} ±0.05
S. *cerevisiae* F-235	0.26 ^{e} ±0.01	0.60 ^{c} ±0.02	1.32 ^{e} ±0.03	2.25 ^{d} ±0.06	2.90 ^{e} ±0.05	3.92 ^{c} ±0.08	4.75 ^{c} ±0.01
S. *cerevisiae* F-25	0.41 ^{c} ±0.01	0.85 ^{b} ±0.03	1.66 ^{c} ±0.05	2.61 ^{c} ±0.04	3.44 ^{c} ±0.08	4.41 ^{b} ±0.03	5.32 ^{b} ±0.10
S. *cerevisiae* FK-727	0.50 ^{b} ±0.02	1.16 ^{a} ±0.04	2.06 ^{b} ±0.02	3.44 ^{b} ±0.06	4.35 ^{b} ±0.05	5.38 ^{a} ±0.05	6.44 ^{a} ±0.04
S. *cerevisiae* FC-620	0.25 ^{e} ±0.02	0.51 ^{d} ±0.03	1.21 ^{f} ±0.03	1.90 ^{e} ±0.04	2.52 ^{f} ±0.04	3.43 ^{d} ±0.06	4.18 ^{e} ±0.06
S. *cerevisiae* FH-620	0.14 ^{g} ±0.02	0.32 ^{e} ±0.02	0.81 ^{h} ±0.03	1.43 ^{f} ±0.05	1.90 ^{h} ±0.05	2.72 ^{f} ±0.04	3.26 ^{g} ±0.06
S. *cerevisiae* FAT-12	0.20 ^{f} ±0.01	0.47 ^{d} ±0.02	1.13 ^{f} ±0.04	1.84 ^{e} ±0.05	2.41 ^{f} ±0.04	3.32 ^{d} ±0.08	4.02 ^{e} ±0.08
S. *cerevisiae* F-514	0.37 ^{c} ±0.01	0.80 ^{b} ±0.03	1.53 ^{d} ±0.04	2.57 ^{c} ±0.07	3.39 ^{c} ±0.03	4.30 ^{b} ±0.02	5.18 ^{b} ±0.01
LSD	0.04	0.08	0.10	0.16	0.15	0.18	0.18

Means followed by different subscripts within column are significantly different at the 5% level.

TABLE V
CONCENTRATION OF CADMIUM IN BAKER'S YEAST OF *SACCHAROMYCES CEREVISAE* STRAINS

Yeast strains	Cadmium concentration (ppm)						
	0.5	1	2	4	6	8	10
S. *cerevisiae* F-707	0.11 ^{e} ±0.01	0.25 ^{c} ±0.01	0.50 ^{d} ±0.02	1.05 ^{d} ±0.04	1.56 ^{e} ±0.05	2.17 ^{f} ±0.06	3.29 ^{d} ±0.08
S. *cerevisiae* FA-91	0.26 ^{a} ±0.01	0.47 ^{a} ±0.02	0.96 ^{a} ±0.03	1.76 ^{a} ±0.04	2.59 ^{a} ±0.06	3.48 ^{a} ±0.06	4.49 ^{a} ±0.07
S. *cerevisiae* FF-725	0.16 ^{d} ±0.01	0.34 ^{b} ±0.01	0.75 ^{b} ±0.03	1.46 ^{b} ±0.04	2.08 ^{c} ±0.04	2.76 ^{c} ±0.06	3.59 ^{c} ±0.07
S. *cerevisiae* F-235	0.15 ^{d} ±0.01	0.33 ^{b} ±0.01	0.65 ^{c} ±0.02	1.27 ^{c} ±0.05	2.00 ^{c} ±0.04	2.83 ^{c} ±0.04	3.68 ^{c} ±0.06
S. *cerevisiae* F-25	0.20 ^{c} ±0.01	0.36 ^{b} ±0.01	0.81 ^{b} ±0.03	1.50 ^{b} ±0.03	2.25 ^{b} ±0.04	3.09 ^{b} ±0.07	4.00 ^{b} ±0.07
S. *cerevisiae* FK-727	0.23 ^{b} ±0.01	0.44 ^{a} ±0.01	0.91 ^{a} ±0.03	1.72 ^{a} ±0.04	2.45 ^{a} ±0.05	3.44 ^{a} ±0.06	4.39 ^{a} ±0.07
S. *cerevisiae* FC-620	0.19 ^{c} ±0.01	0.28 ^{c} ±0.02	0.62 ^{c} ±0.03	1.22 ^{c} ±0.05	1.82 ^{d} ±0.04	2.58 ^{d} ±0.06	3.55 ^{c} ±0.05
S. *cerevisiae* FH-620	0.11 ^{e} ±0.01	0.25 ^{c} ±0.01	0.45 ^{d} ±0.03	1.02 ^{d} ±0.04	1.50 ^{e} ±0.06	2.08 ^{f} ±0.06	3.13 ^{d} ±0.05
S. *cerevisiae* FAT-12	0.12 ^{e} ±0.01	0.26 ^{c} ±0.01	0.62 ^{c} ±0.02	1.20 ^{c} ±0.05	1.61 ^{e} ±0.06	2.39 ^{e} ±0.04	3.50 ^{c} ±0.05
S. *cerevisiae* F-514	0.23 ^{b} ±0.01	0.35 ^{b} ±0.01	0.79 ^{b} ±0.02	1.52 ^{b} ±0.04	2.27 ^{b} ±0.05	3.16 ^{b} ±0.06	3.89 ^{b} ±0.04
LSD	0.02	0.03	0.08	0.13	0.15	0.17	0.19

Means followed by different subscripts within column are significantly different at the 5% level.

Also, it can be noticed that *S. cerevisae* strains had the lowest values of Pb and Cd, they themselves strains had the highest resistance to Pb and Cd. They demonstrate that, the resistant of *S. cerevisae* strains to metals may be return to a relevant role of cell wall in cell protection against entry of metals. Many studies reported that heavy metal toxicity was usually related to the intracellular heavy metal concentration, and the heavy metal tolerance was improved or reduced by weakening or enhancing heavy metal bioaccumulation [22]-[24]. In addition, [25] reported that the highest concentrations of heavy metals by yeast (*Yarrowia lipolytica*) were found in the cell wall and membrane debris while the lowest concentrations were detected in the cytoplasm.

IV. Conclusion

From the previous presentation of the results, it can be found that presence of Pb or Cd metals in the growth media of *S. cerevisiae* strains at concentrations ranged between 0 to 24 ppm for Pb and 0 to 10 ppm for Cd had negative effect on the yield, total viable cells and gassing power at all applied concentrations. This is because Pb and Cd are non essential metals for biological function of the yeast and they are strong inhibitors of its metabolism. In addition, the growth media must be free from Pb and Cd as they inhibited the activity and the growth of baker's yeast at any concentrations. Generally, higher concentrations of metals caused a higher inhibition and the effect of metal ions on yeast growth depended on species and concentration of metal as well as yeast strain. Results reveal also contrary relationship between resistant of *S. cerevisiae* strains and metal concentration in produced baker's yeast. The *S. cerevisiae* FH-620 strain followed by *S. cerevisiae* F-707 strain, then *S. cerevisiae* FAT-12 strain had the highest resistance to Pb and Cd, at the same time, had the lowest values of Pb and Cd concentrations in produced baker's yeast.

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