电生功能水在芽菜生产及果蔬保鲜中的应用研究

Application of Electrolyzed Water in the Production of Sprout and Preservation of Fruits and Vegetables

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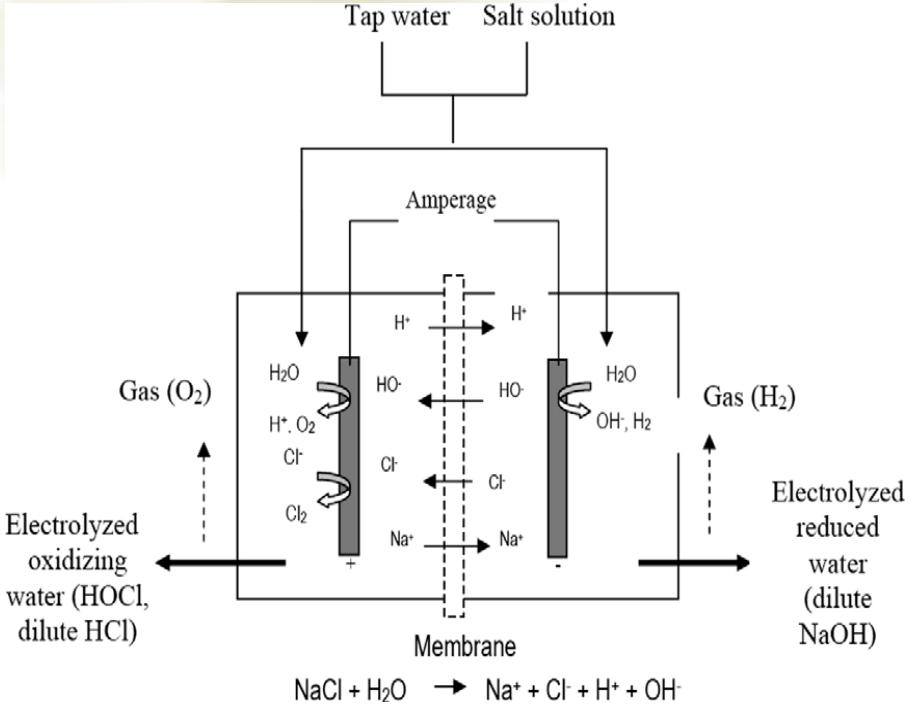
研究背景

电生功能水（Electrolyzed Functional Water），也称电解水或氧化还原电位水，是将水在一种特殊装置中经电场处理后，使水的pH值、氧化还原电位值（ORP）、有效氯浓度（ACC）等指标发生改变而产生的具有特殊功能的酸性电生功能水（以下简称酸性水）和碱性电生功能水（以下简称碱性水）的总称。

电生功能水生成原理



阳极：

$2H_2O \rightarrow 4H^+ + O_2\uparrow + 4e^-$

$2NaCl \rightarrow Cl_2\uparrow + 2e^- + 2Na^+$

$Cl_2 + H_2O \rightarrow HCl + HOCl$

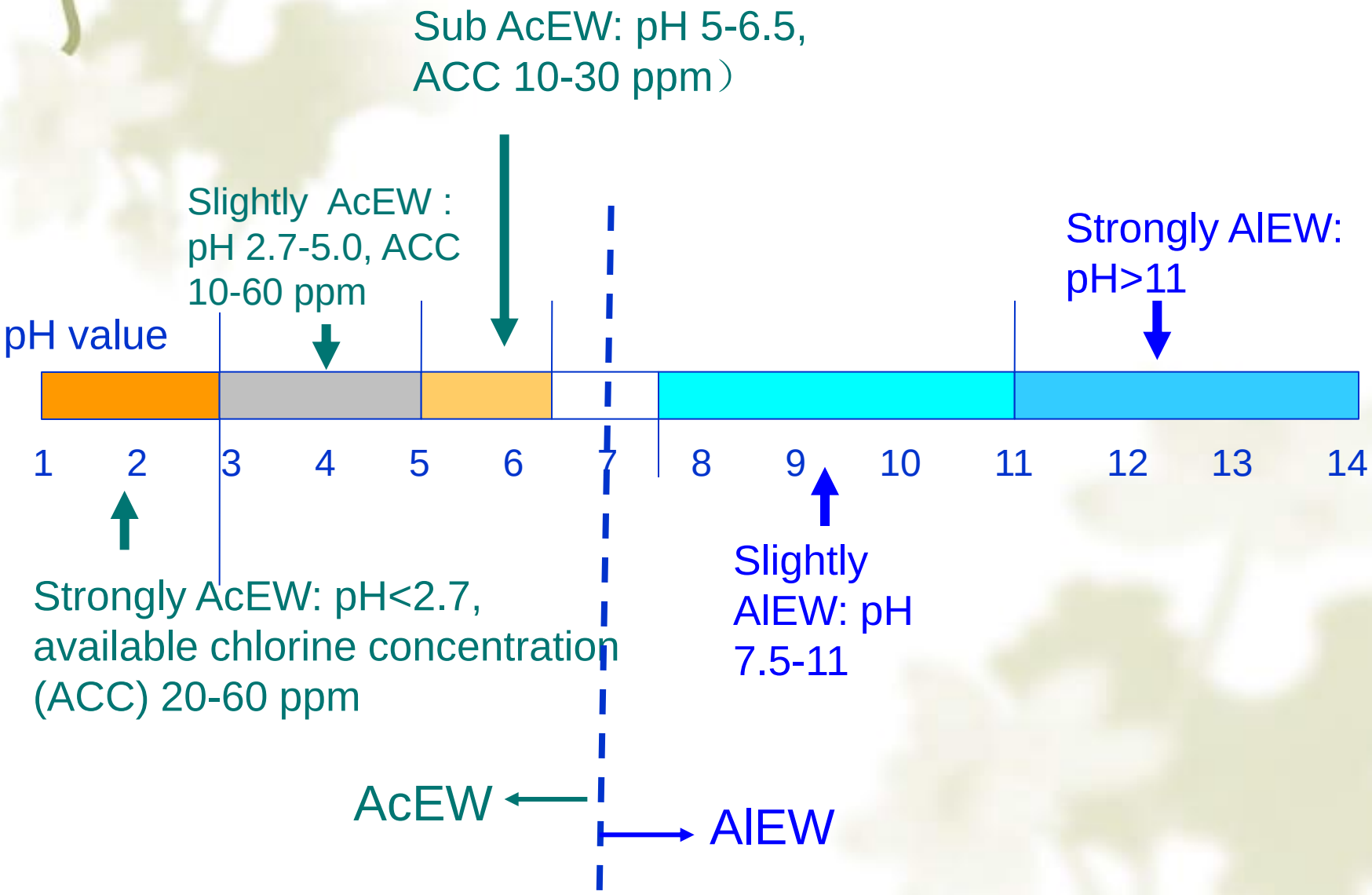
阴极：

$H_2O + 2e^- \rightarrow 2OH^- + H_2\uparrow$

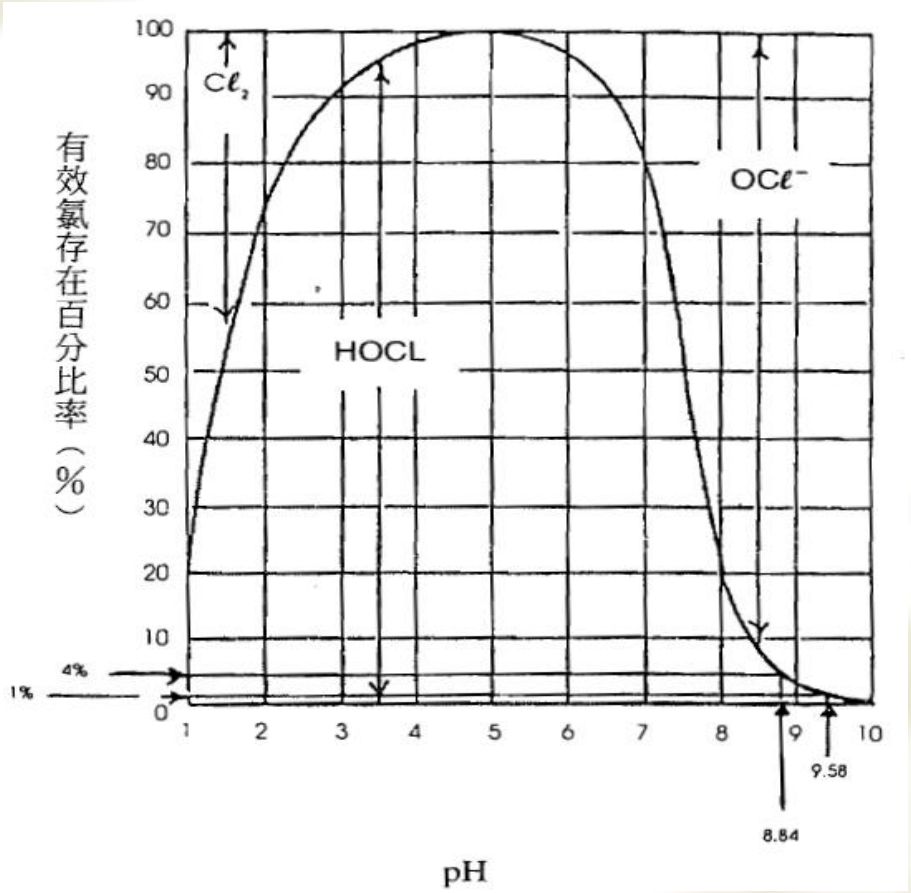
$4H^+ + 4e^- \rightarrow 2H_2\uparrow$

$Na^+ + OH^- \rightarrow NaOH$

Classification of EW



pH值与有效氯的构成关系图

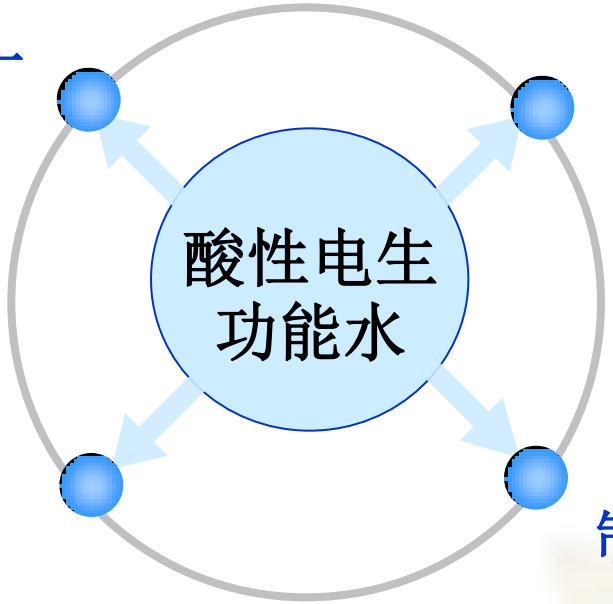


HClO的杀菌力是ClO⁻的80倍

酸性水杀菌的特点

瞬时杀菌，杀菌谱广

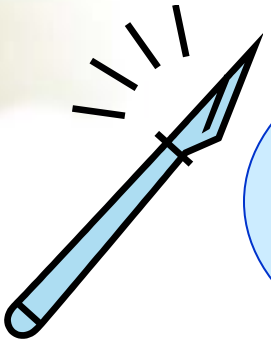
无残留，不污染环境



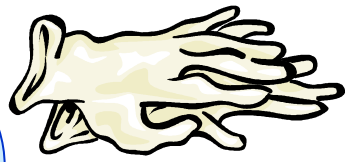
无毒、无副作用
使用安全可靠

制取方便，成本低廉

国内外研究应用现状



医疗：医疗器械的消毒、手消毒、伤口冲洗等



Electrolyzed water

食品加工：加工器械、餐具清洗消毒、蔬菜水果的清洗保鲜、去除毒素、农残等。

农业：种子清洗消毒、减农药无农药栽培、植物生长调节剂等

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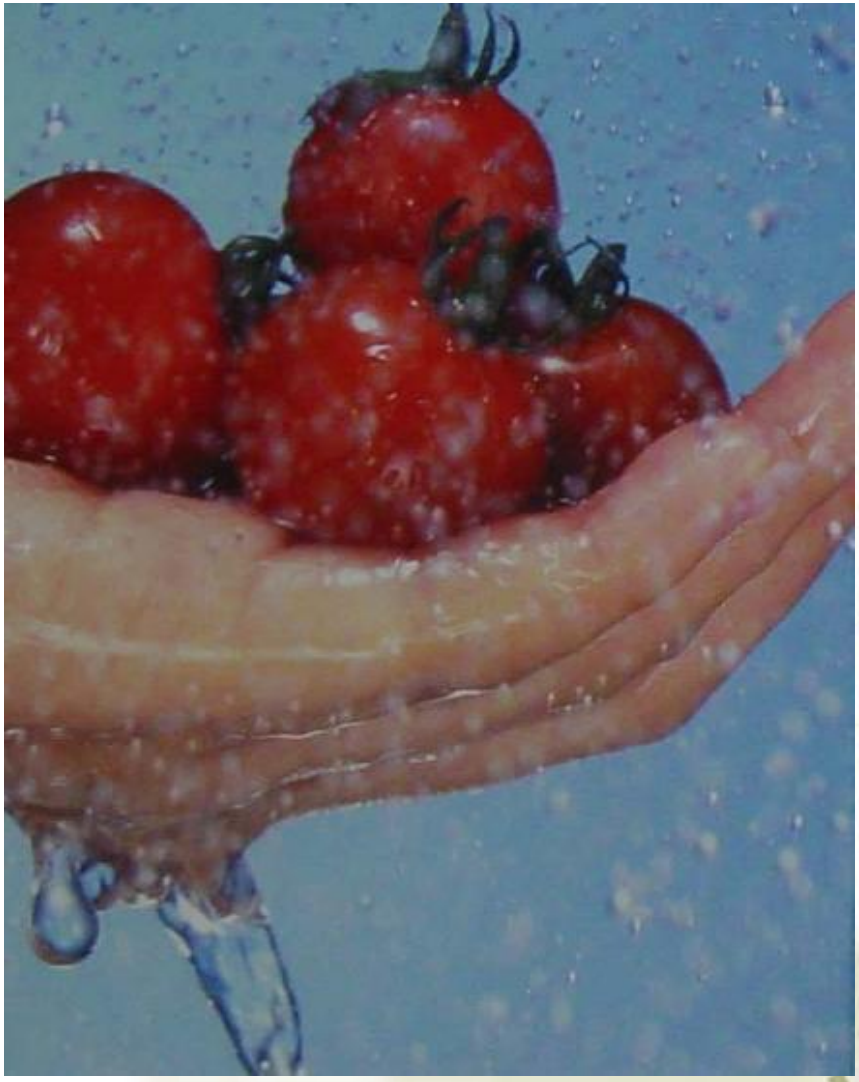
Outline

- 电生功能水在芽菜生长中的应用研究；



- 电生功能水对果蔬保鲜及品质影响。

芽菜生产现状

- 原料携带病原菌及生产过程中微生物浸染产生的微生物超标导致腐败变质；
- 生产过程使用的化学药剂（如消毒剂、生长促进剂）等，导致产品二次污染，安全性下降。

电生功能水对黄豆芽种子的杀菌效果

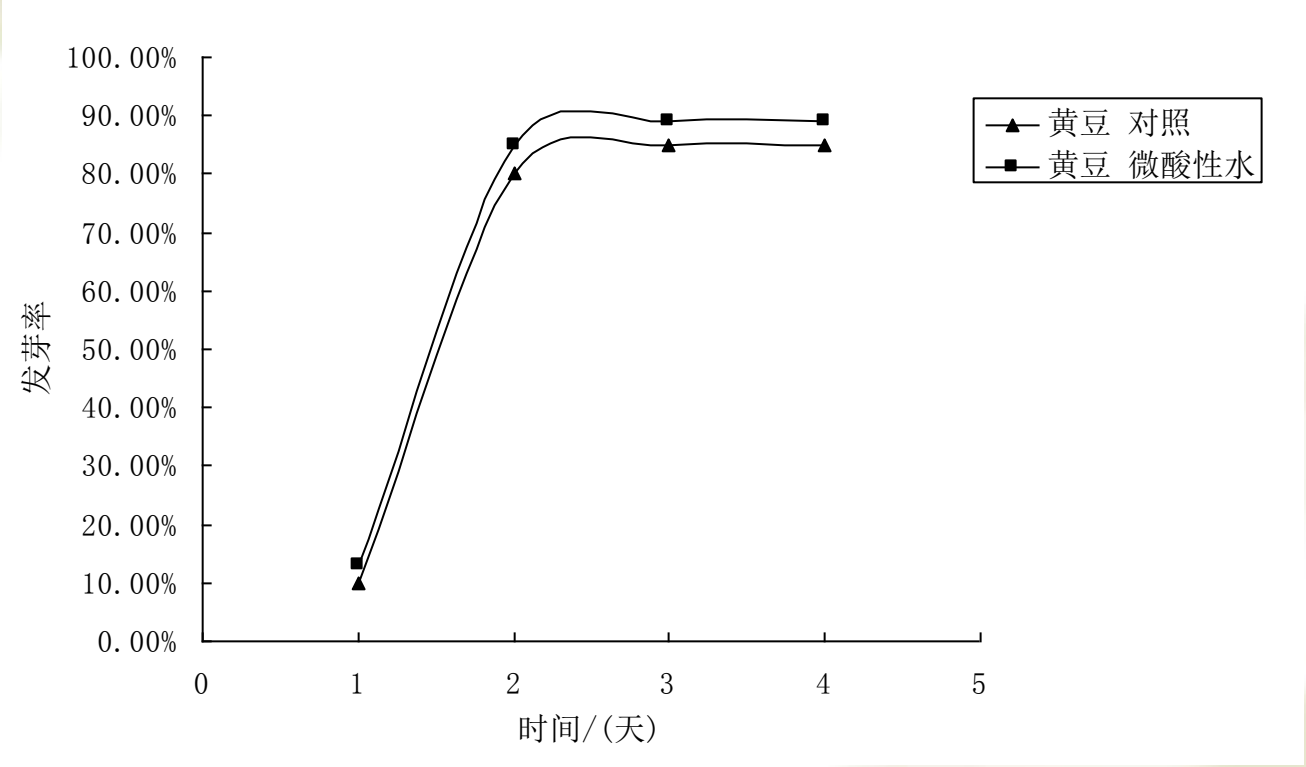
试验用水理化指标

	pH	ACC(mg/L)	ORP(mv)	DO(%sat)	EC(μs/cm)
微酸水	5.78±0.08	29.8±2.3	914.3±3.2	108.4±2.4	772.5±1.4
强碱水	11.42±0.1	——	846.3±5.6	37.8±2.1	1201.8±4.3
自来水	7.80±0.02	——	385.1±3.5	59.9±1.9	501.6±3.5

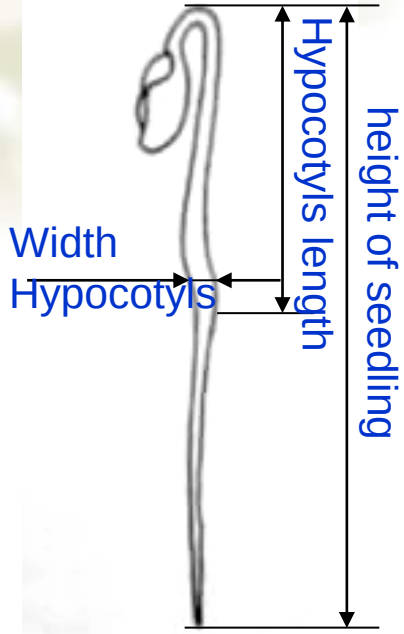
电生功能水对黄豆种子表面微生物总数的影响

处理方式	自来水2h	微酸性水2h	碱性水20min+自来水2h	碱性水20min+微酸性水2h
微生物总数/（logCFU/g）	5.35±0.03	4.72±0.17	4.98±0.16	＜1

电生功能水对黄豆种子发芽率的影响



The morphology index and processing of mungbean sprout



The Morphology index of mungbean sprout

The processing of mungbean sprout：

Mungbean →soaked (8 h)→ germination (in dark placed at 24-26℃)→ Liquid-leached （4 times/day）→ the morphology index of mungbean sprout was measured.

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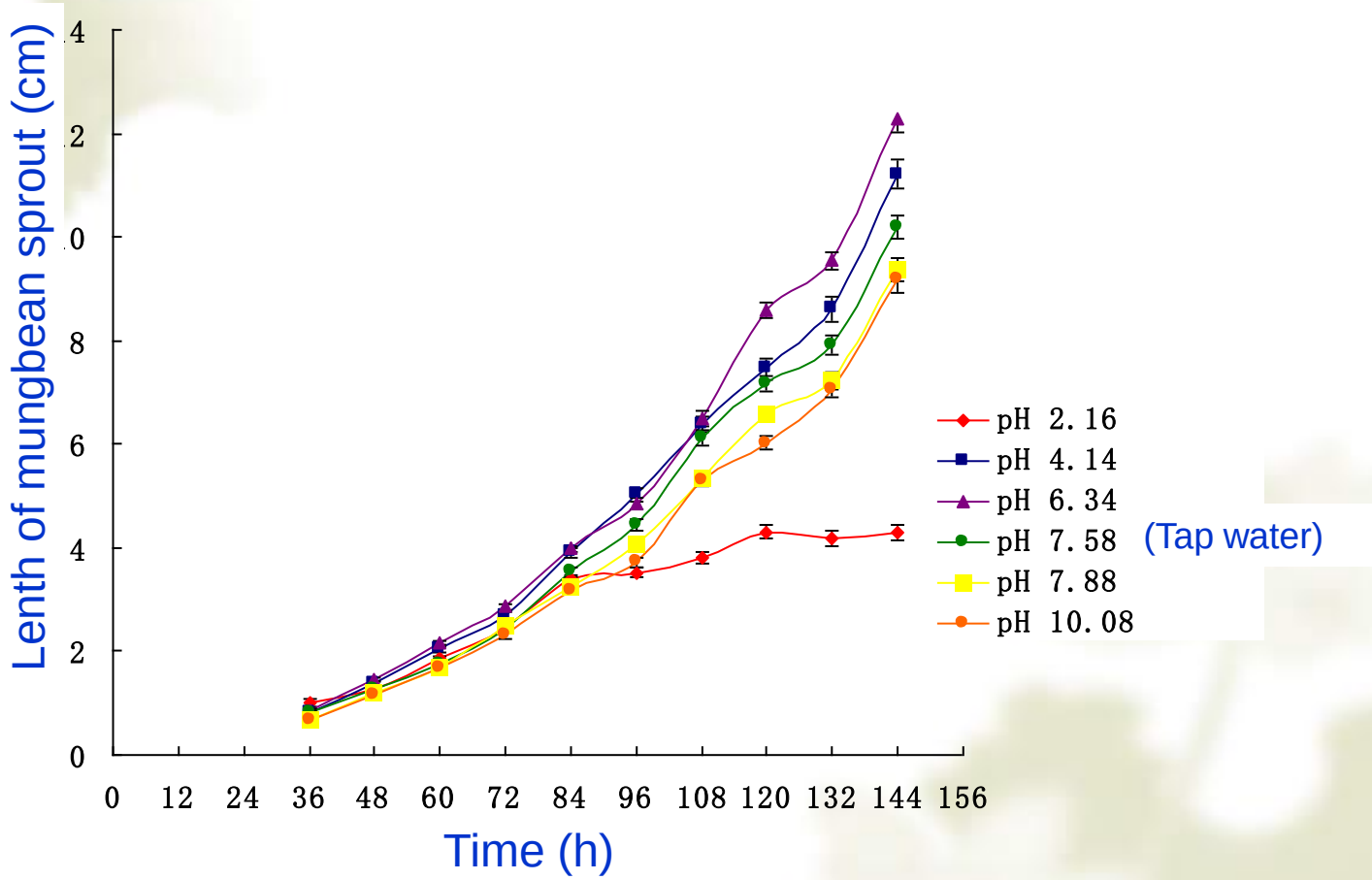
The effect of EW treatment on length of mungbean sprout



The parameters of EW:
pH: 2.2, 4.1, 6.3, 7.6(tap water), 7.9, 10.1;
ACC: 20.2±0.4 ppm (Tap water 0 ppm).

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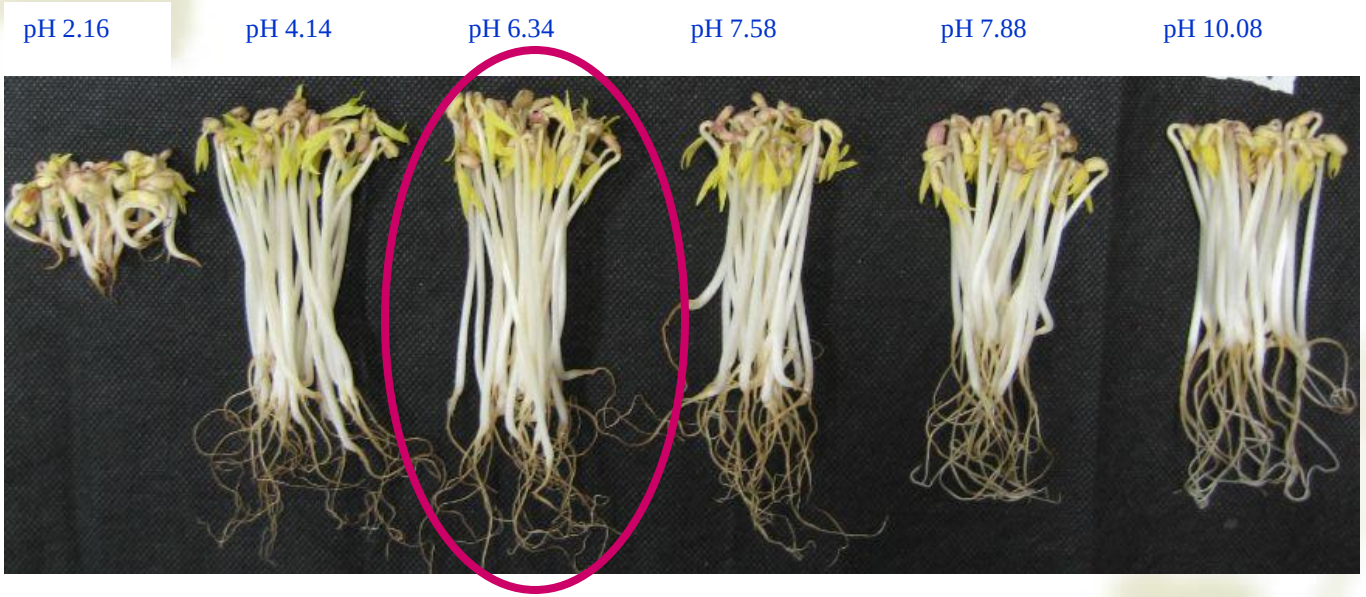
The morphology of mungbean sprouts treated by EW with different pH values after 7 days



The parameters of EW:
pH: 2.2, 4.1, 6.3, 7.6(tap water), 7.9, 10.1;
ACC: 20.2±0.4 ppm (Tap water 0 ppm).

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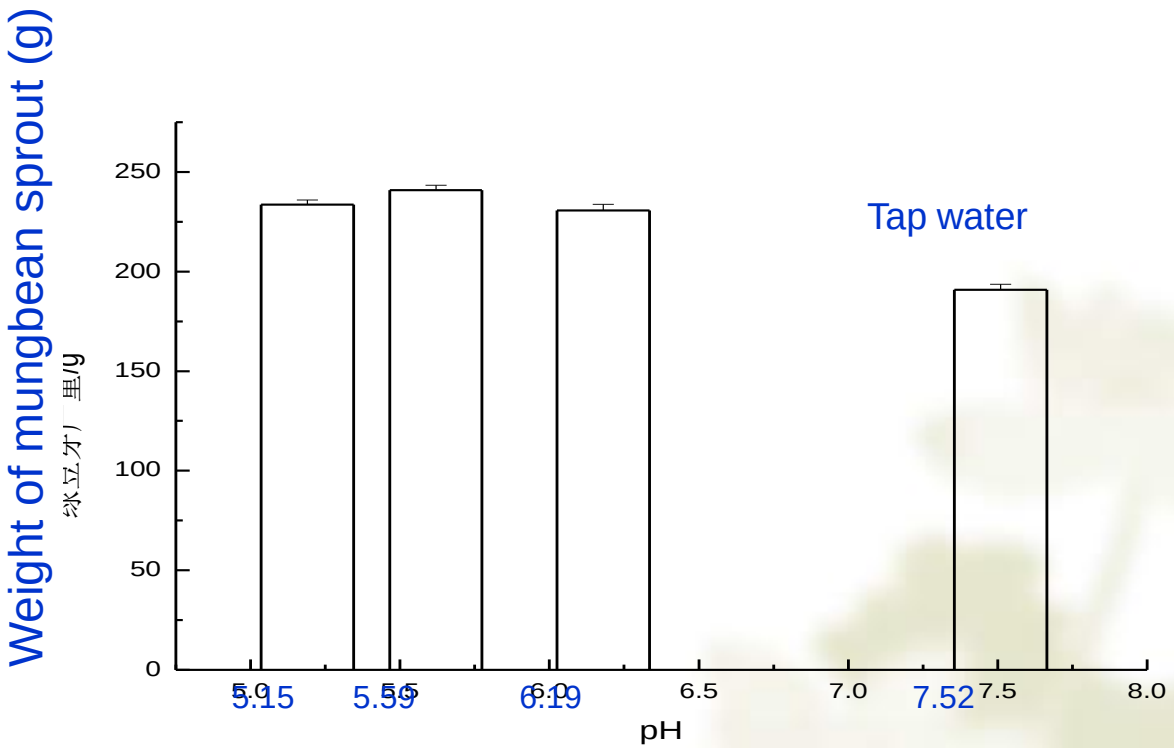
The weight of mungbean sprouts treated by sub AcEW with different pH values



The original weight of each sample is 40g.

The ACC of every sub-AcEW used is same with 20.2±0.4 ppm

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电生功能水对绿豆种子生理活性的影响

➢电解质外渗率测定

电解质外渗率试验用水指标

编号	pH	ORP/mV	ACC/ppm
1	2.0	1149.9	14.5
2	4.1	998.4	16.7
3	5.4	873.5	17.5
4	7.9	489.6	0
5	8.5	597.1	16.6
6	9.9	276.9	17.7

自来水对照 →

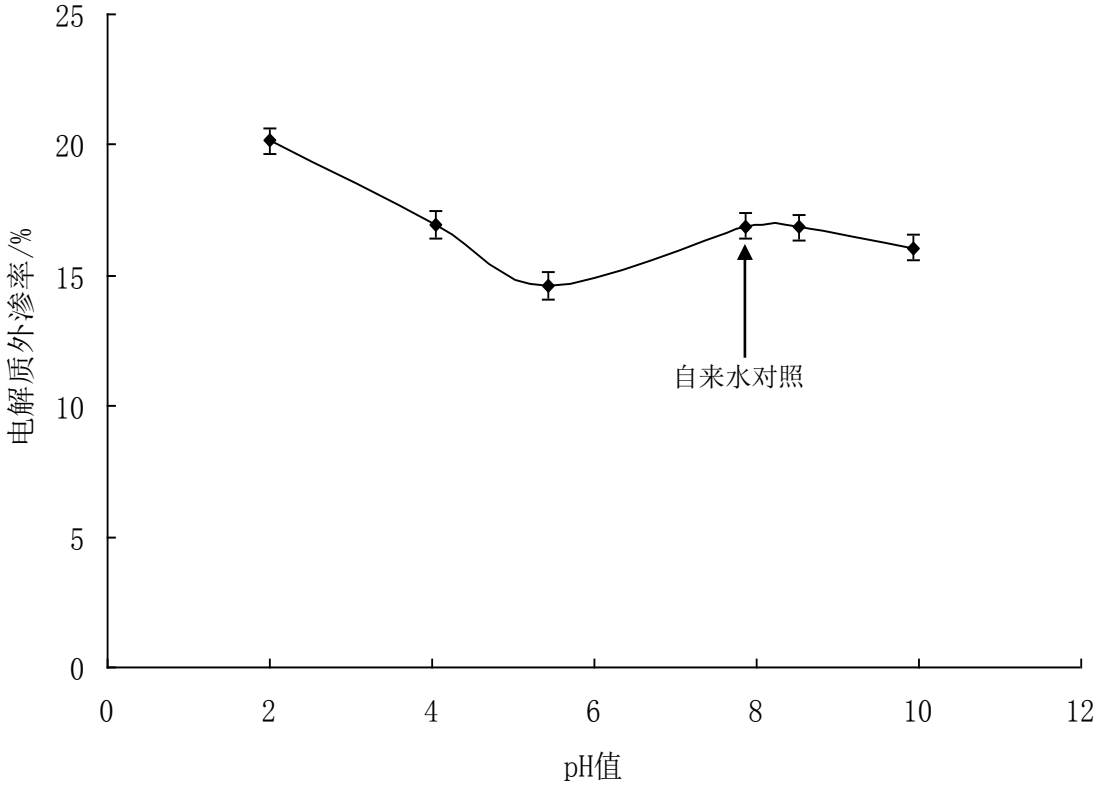
绿豆种子过氧化氢酶活性测定

过氧化氢酶活性试验用水指标

编号	pH	ORP/mV	ACC/ppm
1	2.1	1161.7	17.7
2	4.6	979.1	19.4
3	5.5	850.8	19.0
4	7.8	642.5	19.0
5	7.8	340.6	0
6	9.5	97.8	20.8

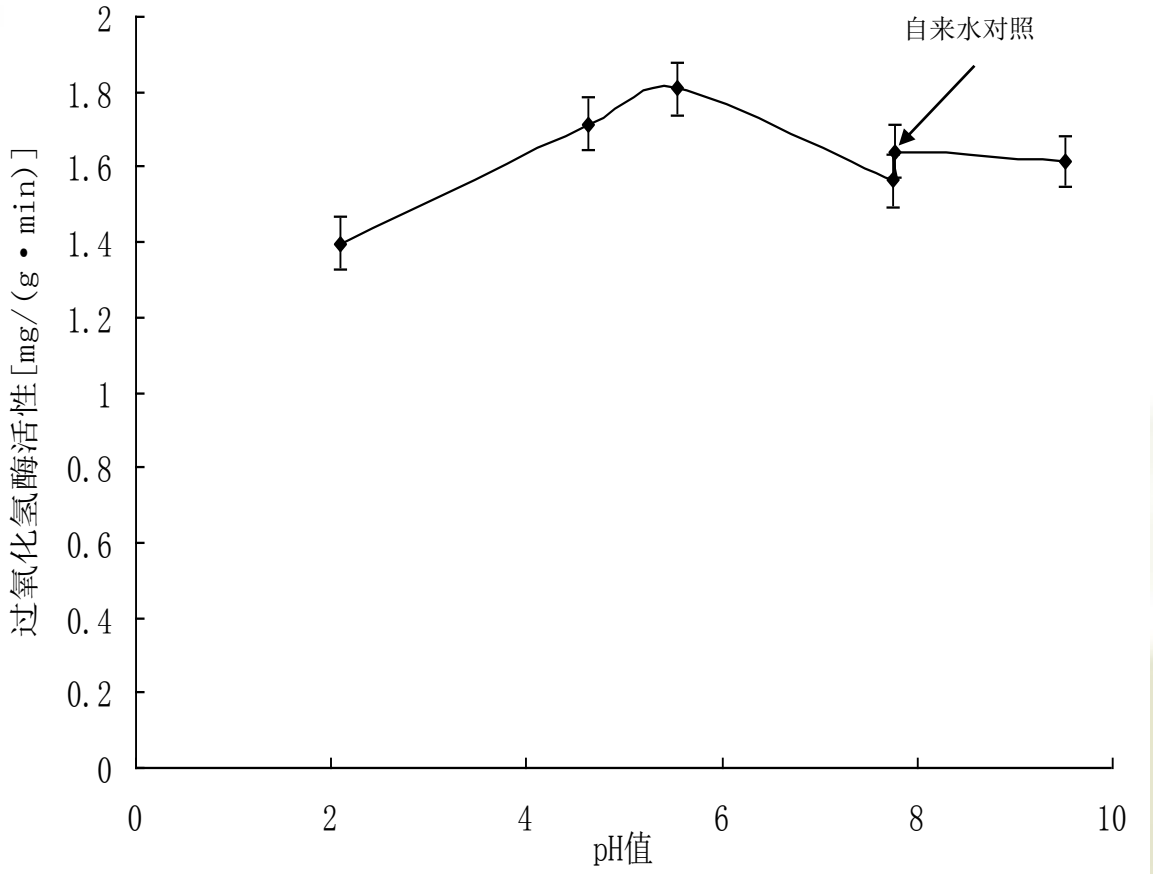
自来水对照 →

电生功能水及对照自来水对浸泡绿豆电解质外渗率的影响



pH值对电解质外渗率的影响

电生功能水及自来水对照对绿豆种子过氧化氢酶活性的影响



pH值对过氧化氢酶活性的影响

电生功能水对果蔬杀菌及保鲜效果研究

- 草莓
- 葡萄
- 番茄
- 菠菜
- 桃子
- 芫荽

果蔬保鲜研究-草莓的保鲜

试验用草莓品种为“全明星”*(Fragaria Ananassa Duch.cv. All star)*，于2002年4月16日采自河北省满城县陶佐村草莓园。

将4kg草莓浸入处理液中浸泡10min，捞出晾干，然后将草莓分别分装于聚酯塑料袋内，每个塑料袋装1kg，每处理组设4个重复，然后敞口置于温度为0℃、湿度为90-95%的冷库中贮藏12天，贮藏期内每3天测定各项指标。

处理用水	pH	ORP(mV)	ACC（ppm）
酸性水	2.5±0.1	1150±20	100±10
含2%氯化钙的酸性水	6.0±0.1	860±20	100±15
对照水	7.1±0.1	850±10	

贮藏12天后

好果率比较

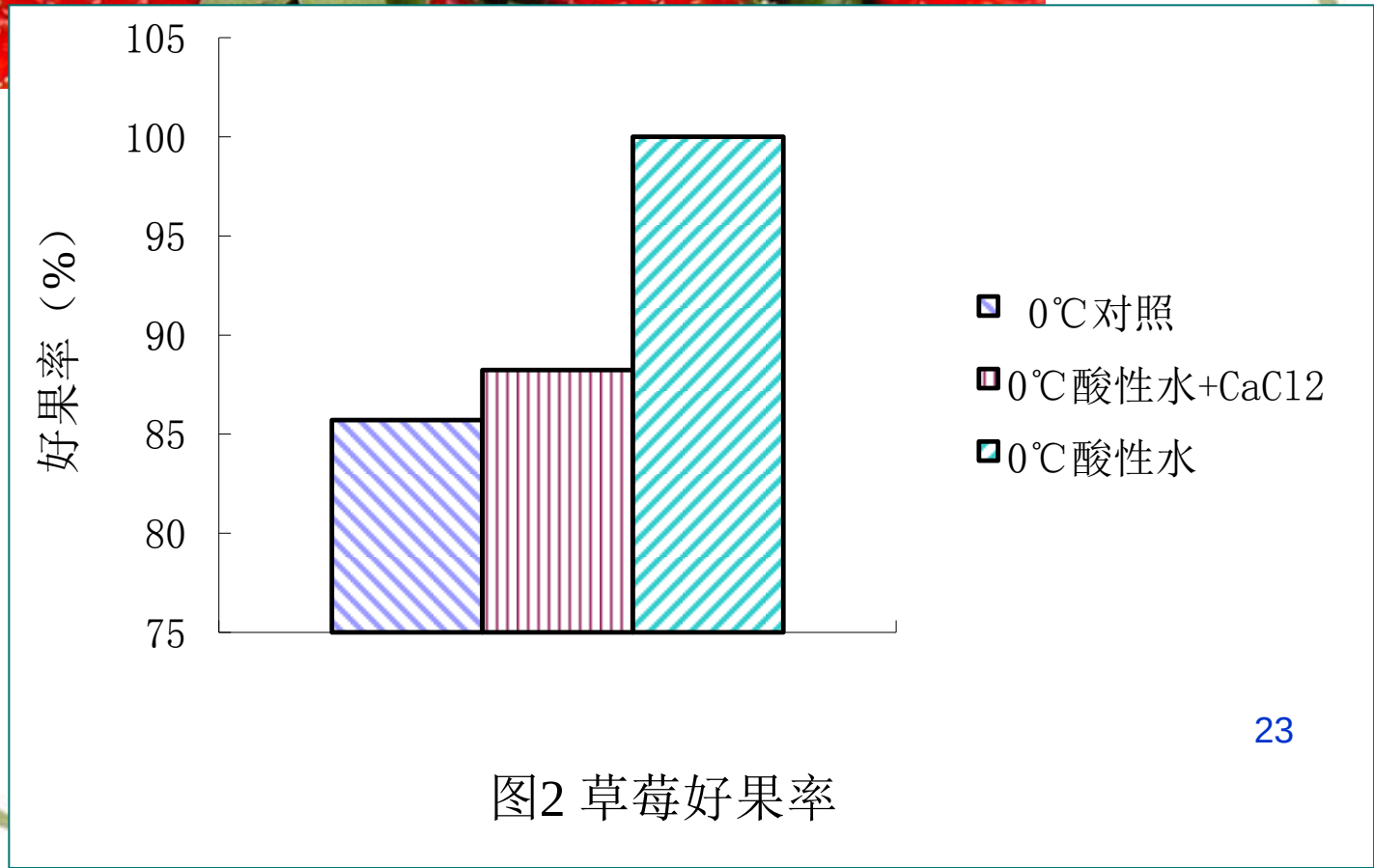


图2 草莓好果率

电生功能水保鲜草莓杀菌效果

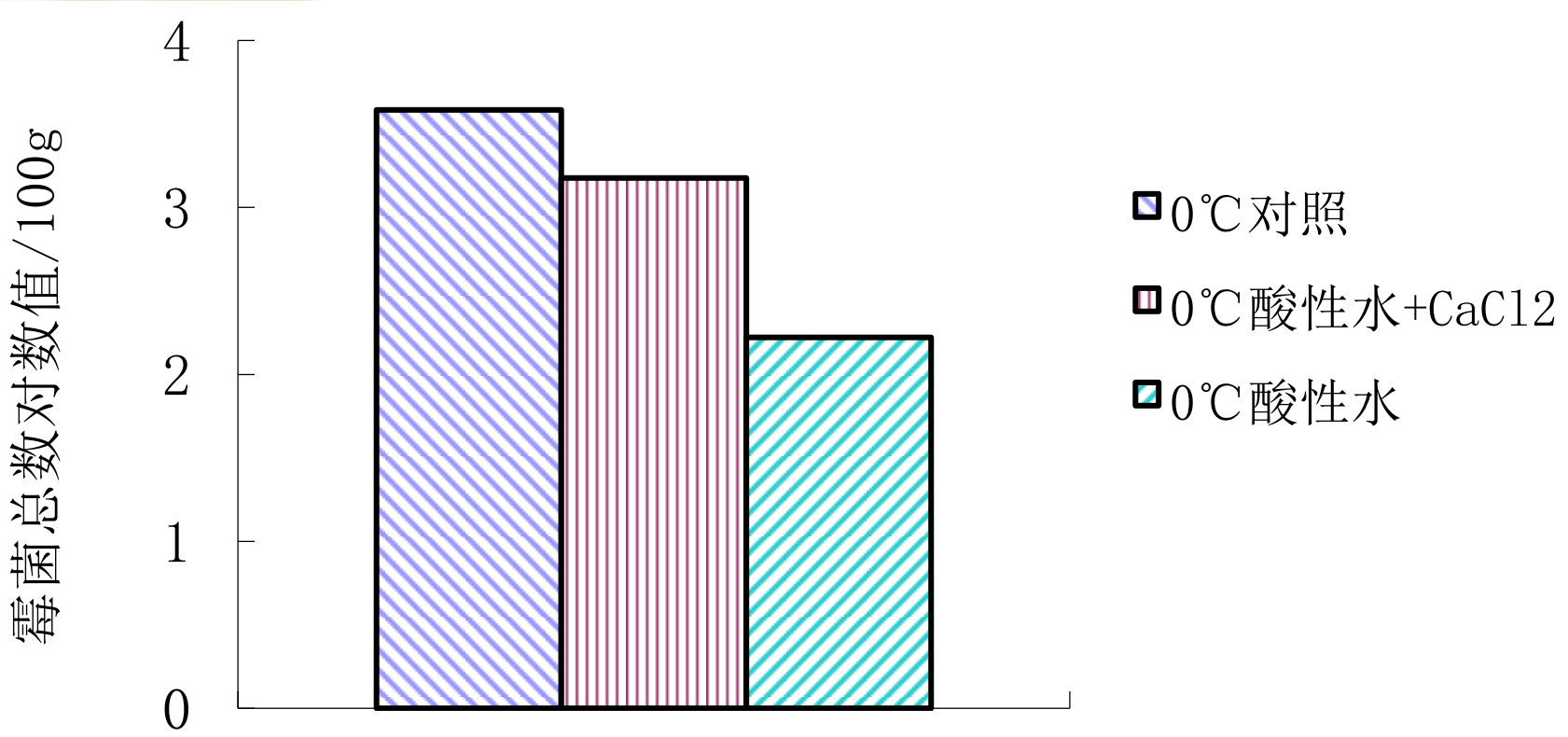


图1 草莓霉菌总数

电生功能水草莓保鲜效果

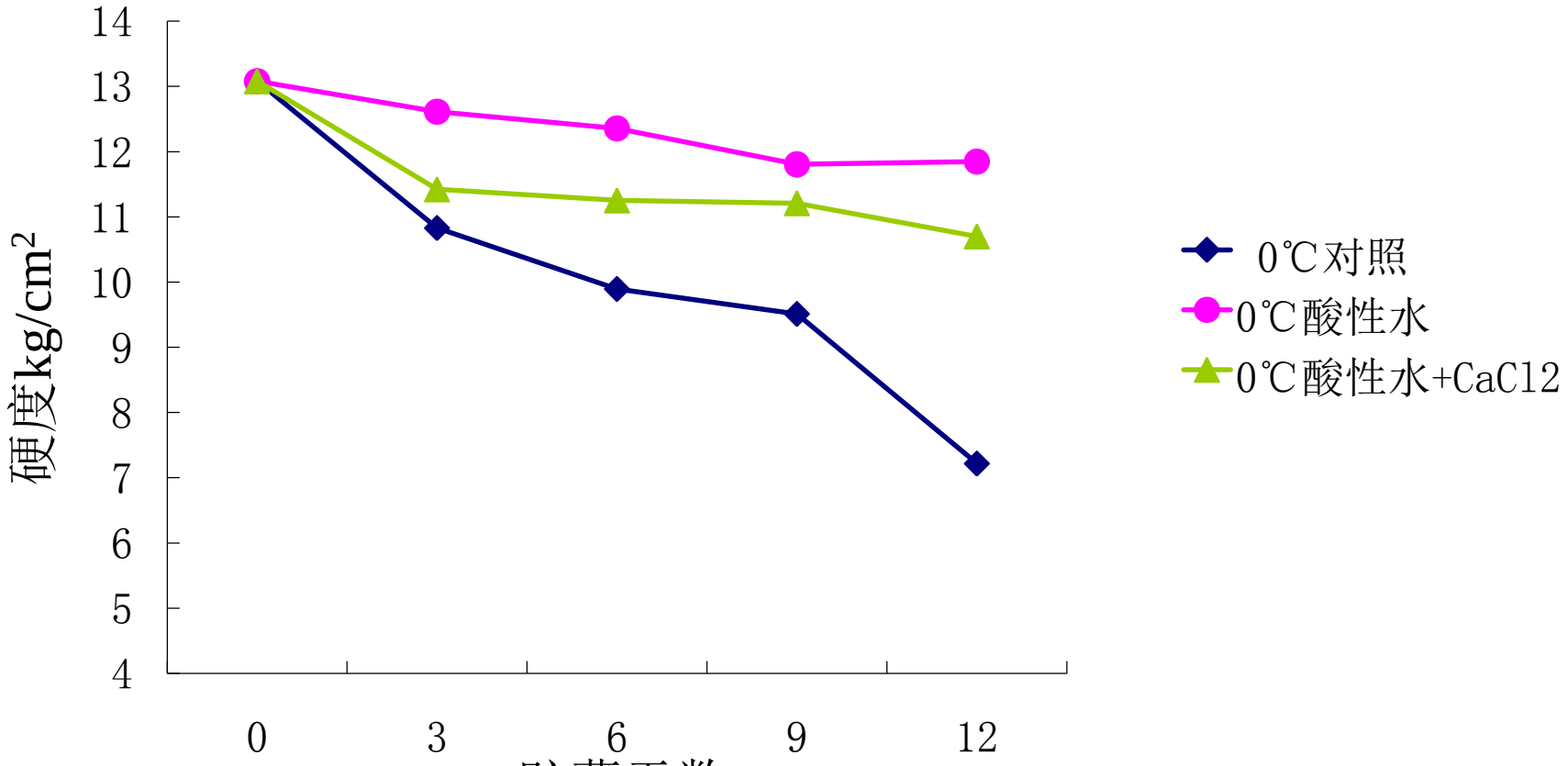


图4 草莓硬度变化

电生功能水处理草莓保鲜机理探讨

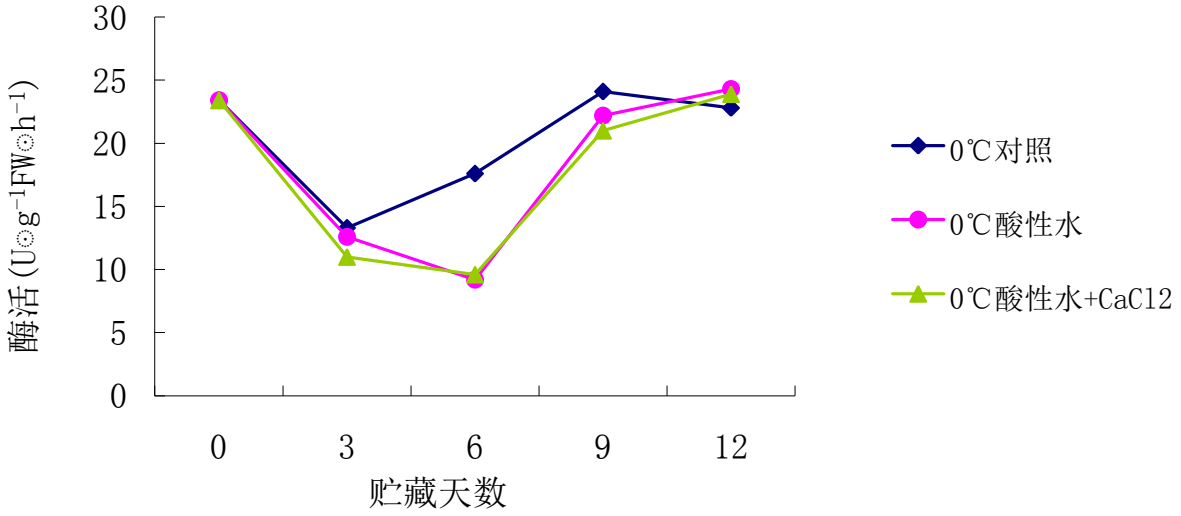


图6 羧甲基纤维素酶活

实验表明 不仅抑制微生物生长，也影响采后生理

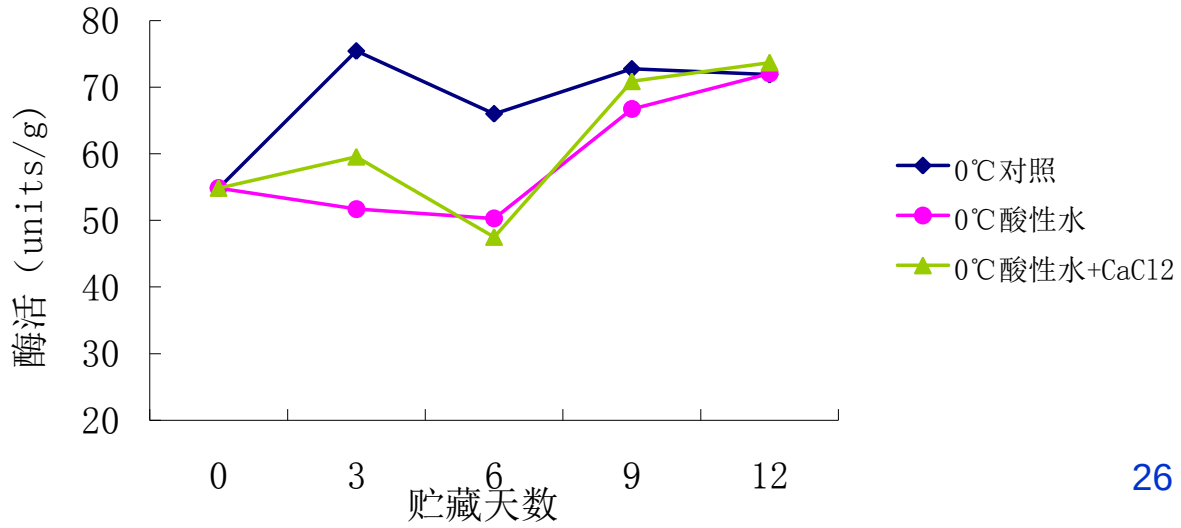


图7 多聚半乳糖醛酸酶活

EFFICACY OF SLIGHTLY ACIDIC ELECTROLYZED WATER (SAEW) FOR REDUCING MICROBIAL CONTAMINATION ON FRESH-CUT CILANTRO

TABLE 1.
PHYSICAL AND CHEMICAL PARAMETERS OF DIFFERENT SOLUTIONS*

Solutions	pH	ORP (mV)	ACC (mg/L)
Tap water (TW)†	7.69 ± 0.06	370 ± 6	ND‡
Slightly acidic electrolyzed water (SAEW)	5.85 ± 0.05	815 ± 12	19.46 ± 0.32
Acidic electrolyzed water (AEW)	2.48 ± 0.07	1134 ± 11	79.35 ± 0.46
NaClO solutions	10.65 ± 0.07	499 ± 5	103.39 ± 1.25
Mild heat SAEW (45 ± 1C)	5.92 ± 0.06	800 ± 7	18.23 ± 0.54
Mild heat AEW (45 ± 1C)	2.49 ± 0.05	1127 ± 10	73.85 ± 2.23

* Values represented the mean ± SD ($n = 5$).
† TW was the tap water come from China Agricultural University, the residue of chlorine was around 0.1 mg/L.
‡ ND, not detected.

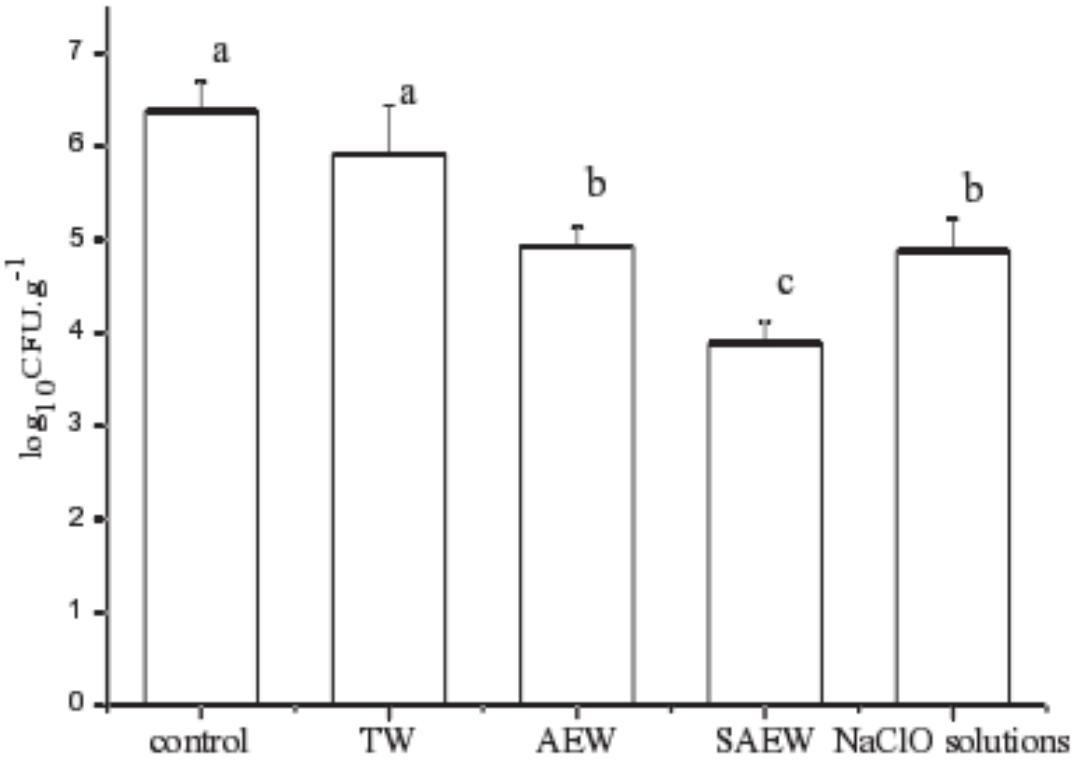


FIG. 1. SURVIVAL POPULATION OF *E. COLI* OF FRESH-CUT CILANTRO INOCULATED BY *E. COLI* O78 AND TREATED BY DIFFERENT SOLUTIONS FOR 5 MIN

All treatments and determinations were performed in triplicate. The treatment solutions were tap water (TW), acidic electrolyzed water (AEW), slightly acidic electrolyzed water (SAEW) and NaClO solutions. The different letters indicate significant differences ($P < 0.05$).

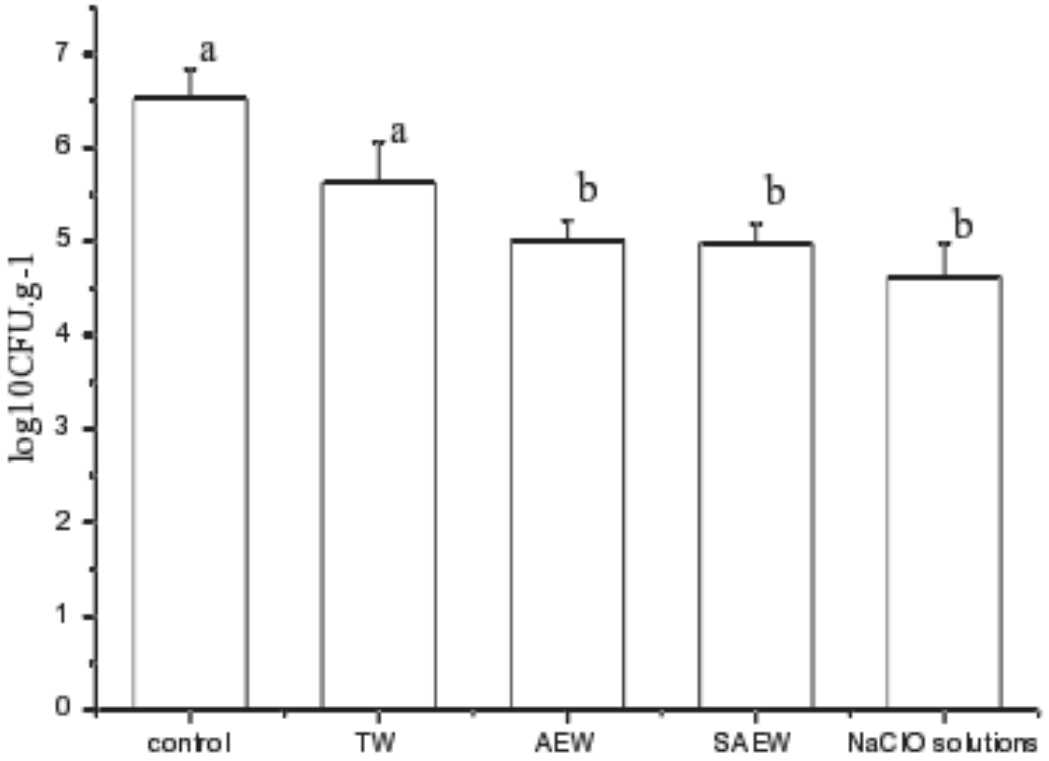


FIG. 2. SURVIVAL POPULATION OF *E. COLI* AND *B. SUBTILIS* OF FRESH-CUT CILANTRO INOCULATED BY THE MIXTURE OF *E. COLI* O78 AND *B. SUBTILIS* 1.1849 AND TREATED BY DIFFERENT SOLUTIONS FOR 5 MIN

All treatments and determinations were performed in triplicate. The treatment solutions were tap water (TW), acidic electrolyzed water (AEW), slightly acidic electrolyzed water (SAEW) and NaClO solutions. The different letters indicate significant differences ($P < 0.05$).

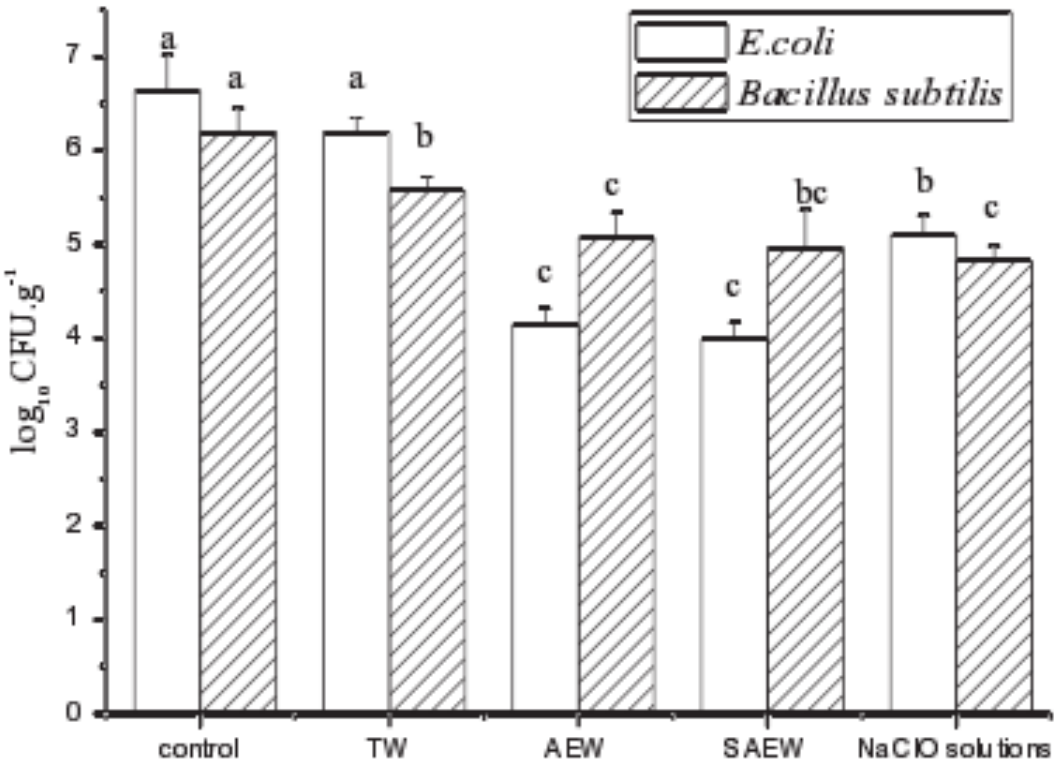


FIG. 3. SURVIVAL POPULATION OF *B. SUBTILIS* OF FRESH-CUT CILANTRO INOCULATED BY *B. SUBTILIS* 1.1849 AND TREATED BY DIFFERENT SOLUTIONS FOR 5 MIN

All treatments and determinations were performed in triplicate. The treatment solutions were tap water (TW), acidic electrolyzed water (AEW), slightly acidic electrolyzed water (SAEW) and NaClO solutions. The different letters indicate significant differences ($P < 0.05$).

SURVIVAL POPULATIONS OF DIFFERENT NATURAL MICROFLORA OF FRESH-CUT CILANTRO TREATED BY DIFFERENT SOLUTIONS

Treatments	Microbial counts		
	Coli-forming bacteria	Molds and yeasts	Total aerobic bacteria
Control	6.57 ± 0.38^{a}	5.35 ± 0.07^{a}	6.99 ± 0.24^{a}
TW	5.98 ± 0.15^{ab}	4.77 ± 0.40^{a}	6.02 ± 0.12^{b}
SAEW	5.49 ± 0.21^{b}	3.71 ± 0.31^{bc}	5.43 ± 0.22^{c}
Mild heat SAEW	5.30 ± 0.18^{b}	3.98 ± 0.22^{b}	5.65 ± 0.16^{c}
AEW	4.76 ± 0.07^{c}	3.31 ± 0.36^{c}	4.41 ± 0.11^{c}
Mild heat AEW	ND^{d}	ND^{d}	2.94 ± 0.35^{d}
NaClO solutions	5.54 ± 0.30^{ab}	4.09 ± 0.27^{b}	5.30 ± 0.24^{c}

Values are the means of three replicated measurements ± standard deviation; the different letters indicate significant differences ($P < 0.05$) and comparison of means were formed using Duncan's multiple comparison test; ND means not detected.

不同杀菌剂对菠菜的杀菌效果及贮藏期间微生物数量

不同处理组	不同贮藏时间菠菜表面的可检测的微生物数量logcfu/g			
	5 min	3d	6d	9d
对照组	5.96±0.17a	6.25±0.09a	6.54±0.14a	6.95±0.12a
自来水组	5.64±0.12b	5.97±0.11b	6.45±0.13a	7.15±0.08a
强酸水组	3.89±0.08d	4.07±0.09d	4.60±0.17c	5.69±0.15c
微酸水组	3.73±0.08d	3.94±0.12d	4.52±0.18c	5.57±0.09c
次氯酸钠组	4.82±0.07c	5.16±0.08c	5.64±0.15b	6.24±0.21b

不同杀菌剂处理对贮藏期间菠菜品质的影响

	不同处理组菠菜贮藏期间营养物质及有害物质含量的变化											
	叶绿素mg/g				可溶性固形物%				亚硝酸盐ug/g			
	0d	3d	6d	9d	0d	3d	6d	9d	0d	3d	6d	9d
1	0.89	0.73	0.44	0.32a	7.38	3.46	4.68	4.48a	0.92	1.05	1.42	2.15a
2	0.89	0.54	0.46	0.37a	7.38	2.78	4.26	4.38a	0.92	1.06	1.44	2.24a
3	0.89	0.56	0.53	0.50b	7.38	3.34	4.48	4.12b	0.92	0.97	1.02	1.46b
4	0.89	0.55	0.50	0.46b	7.38	3.40	3.80	4.46a	0.92	0.96	1.02	1.41b
5	0.89	0.61	0.53	0.46b	7.38	3.68	3.26	4.02c	0.92	0.97	1.03	1.45b

微酸水不同处理方式对桃子杀菌效果的比较

不同处理组	不同处理组的桃子可检测的微生物数量logcfu/g			
	微生物总数		霉菌、酵母菌总数	
	5 min	8d	5min	8d
对照组	4.19±0. 07a	5.26±0. 09a	3.43±0. 13a	3.65±0. 17a
微酸水震荡浸泡	2.84±0. 11c	3.75±0. 09c	1.99±0. 17c	2.15±0. 08b
微酸水静电喷雾	3.96±0. 12b	4.79±0. 07b	3.15±0. 06b	3.52±0. 10a
微酸水普通喷洒	4.02±0. 05b	4.88±0. 07b	3.19±0. 09b	3.62±0. 13a

微酸水对不同品种桃子浸泡处理后保鲜效果的比较

贮藏时间（天）			0	2	4	6	8	10	12
北京1号（早熟型）	硬度 Kg/cm²	CK	8.24	4.31	0.50	0.20			
		SEW	8.24	4.40	2.57	0.98	0.21		
	可溶性固形物%	CK	11.18	10.67	9.82	9.12			
		SEW	11.18	11.04	10.32	9.68	9.29		
	腐烂率%	CK	0	3.70	13.30	35.6			
		SEW	0	0	6.70	16.80	22.20		
	褐变指数%	CK	0	9.38	34.75	40.63			
		SEW	0	3.13	12.50	34.38	37.50		
大久保（中熟型）	硬度 Kg/cm²	CK	11.08	9.04	6.55	5.02	4.08	2.00	1.00
		SEW	11.08	7.75	7.73	6.12	5.49	4.90	2.90
	可溶性固形物%	CK	11.35	11.76	12.46	11.71	10.98	10.26	10.08
		SEW	11.35	11.69	12.04	11.57	10.99	10.68	10.46
	腐烂率%	CK	0	0	0	5.10	12.80	22.40	35.70
		SEW	0	0	0	0	3.40	4.70	12.50
	褐变指数%	CK	0	0	5.00	6.80	10.8	15.30	17.6
		SEW	0	0	4.50	5.00	9.4	11.30	15.5
绿化九（晚熟型）	硬度 Kg/cm²	CK	11.80	8.70	6.40	4.32	2.10	1.00	
		SEW	11.80	9.10	6.80	6.00	4.80	3.20	0.80
	可溶性固形物%	CK	12.20	11.00	11.50	9.10	10.90	10.90	9.70
		SEW	12.20	10.70	11.60	10.40	11.00	10.60	10.70
	腐烂率%	CK	0	0.62	1.24	2.47	7.41	10.30	15.37
		SEW	0	0	0	0	0	0.62	1.24
	褐变指数%	CK	0	0	1.70	6.70	20.00	33.30	54.20
		SEW	0	0	0	1.70	5.00	13.30	25.00

电生功能水对桃子杀菌保鲜

结　论

- 电生功能水处理对豆芽原料有杀菌作用，微酸水促进芽菜生长作用最为明显。电解质外渗率和过氧化氢酶活性变化规律与上述效果吻合。
- 酸性水处理能够减少采后果蔬微生物数量，保持贮藏中果蔬外观及营养品质，提高食用安全性。

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Thank you for your attention!

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