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Comparison of Nutritional and Functional Components and Total Antioxidant Capacity of Different *Momordica charantia* Varieties

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Abstract The differences of nutrient content, functional component content and total antioxidant capacity of 25 different varieties (lines) of *Momordica charantia* were compared, and the correlation between functional components and the total antioxidant capacity of *Momordica charantia* was analyzed, so as to provide the basis for the breeding of fresh and processed *Momordica charantia* varieties and the development of functional food of *Momordica charantia*. The results showed that the contents of vitamin C, soluble protein, cellulose, amino acid and total acid in pulp of different varieties (lines) were significantly different, the average values were 85.71 μg/g, 7.98 mg/g, 319.04 mg/g, 1.45 mg/g, 0.41%, and the coefficient of variation were 28.47%, 29.07%, 11.05%, 43.45% and 12.20%, respectively. There were significant differences in the contents of total saponins, polysaccharides, flavonoids and total phenols in different varieties (lines), with the average values of 5.02 μg/g, 38.36 mg/g, 2.64 mg/g and 7.68 mg/g, respectively. The number of variation lines was 45.62%, 25.47%, 21.97% and 18.49%, respectively. The average antioxidant capacity of DPPH (1,1-diphenyl-2-picrylhydrazy), $ABTS^{+\cdot}$ (2,2'-azinobis-3-ethylbenzothiazoline-6-sulphonic acid diammonium salt) and FRAP (Ferric reducing/antioxidant power) were 1.73 μmol Trolox/g, 67.38 μmol Trolox/g and 11.62 μmol Trolox/g, respectively, and the variation coefficients were 19.65%, 17.25% and 31.50%, respectively. There was a significant correlation between total phenol content and total antioxidant capacity of *Momordica charantia*. Over all, there were significant genotypic differences in the contents of nutrients, functional components and antioxidant value in the pulp of 25 varieties (lines), and the total phenol content in the pulp was the main material basis for the antioxidant activity of *Momordica charantia*. In the breeding and cultivation of new bitter gourd varieties, the corresponding varieties should be selected according to different uses, which is conducive to the development of the advantages and commercial value of the varieties.
Keywords *Momordica charantia*; Nutritional components; Functional components; Total antioxidant capacity; Correlation

Balsam pear (*Momordica charantia* L.), also known as Lianggua in Chinese, belongs to the *Momordica* genus of Cucurbitaceae family, is a kind of characteristic medicinal vegetables. The tender fruit of *Momordica charantia* contains rich nutrients, such as vitamin C, amino acid, crude protein, cellulose, soluble sugar, etc., among which the content of Vc ranks first among melon vegetables, and greatly exceeds that of tomato. *Momordica charantia* fruit also contains saponins (Keller et al., 2011), polysaccharides (Zhang et al., 2010), flavonoids (Lin et al., 2011), phenols (Huang et al., 2014) and other physiological active ingredients. It has physiological functions such as lowering blood sugar, lowering blood pressure, lowering blood lipid, antioxidant, clearing heat and detoxifying, improving immunity, etc., and has high medicinal value (Yuan, 2006; Li, 2007; Luo and Zhang, 2016). In recent years, with the enhancement of people's health awareness, *Momordica charantia* has attracted more and more attention and is cultivated all over the country.

The content of nutrients and active substances in plants often varies from variety to variety, and *Momordica charantia* is no exception. Du et al. (2014, Chinese Agricultural Science Bulletin, 30(1): 226-231) found that there were significant differences in nutrient composition and physiological active substances of 22 varieties (lines) of *Momordica charantia*.. Cao et al. (2014) found that there were significant differences in the content of polysaccharides and saponins in *Momordica charantia* among different varieties. Liu et al. (2017) concluded that there were significant differences in saponin content, antioxidant activity and α-glucosidase inhibition rate in the pulp of 13 different varieties of *Momordica charantia*. Therefore, it is of great significance to select the varieties of bitter melon which are rich in certain nutrients or physiological active substances and have strong antioxidant activity for consumer' diet orientation and the development of health products with *Momordica charantia* as raw materials. At present, the existing studies are limited to the comparison of the content of nutrients and functional substances in different *Momordica charantia* varieties, and the analysis of antioxidant activity of functional substances. There is no study on the comparison of antioxidant activity in pulp of different *Momordica charantia* varieties, and the correlation analysis between functional substance content and activity is also few. In this study, the differences of nutrient content, functional substance content and total antioxidant activity in pulp of 25 different varieties (lines) of *Momordica charantia* L. were compared, and the correlation between functional substance content and activity was analyzed, in order to provide theoretical basis for the breeding of high-quality functional *Momordica charantia* L. varieties and the development of functional food of *Momordica charantia* L..

1 Results and Analysis

1.1 Comparison of nutritional constituents in different varieties of *Momordica charantia*

There were some differences in the nutritional components of different *Momordica charantia* varieties (Table 1; Table 2), the Vc content of different *Momordica charantia* varieties (lines) ranged from 56.65 to 158.65 μg/g, with an average value of 85.71 μg/g, among which the highest Vc content was No.10, and the lowest Vc content was No.14. There were significant differences in VC content among different varieties (lines), and the coefficient of variation was 28.47%. The soluble protein content of 25 *Momordica charantia* varieties (lines) ranged from 4.70 mg/g to 13.30 mg/g, with an average value of 7.98 mg/g, with the highest content being No.9 and the lowest content being No.15, and the coefficient of variation among different varieties (lines) was 29.07%. The cellulose content of different *Momordica charantia* varieties (lines) varied from 262.28 to 399.46 mg/g, with an average value of 319.04 mg/g, with the highest content being No.14 and the lowest content being No.16. The difference among varieties (lines) was relatively small, and the coefficient of variation was 11.05%. The amino acid content of different *Momordica charantia* varieties (lines) varied from 0.31 to 2.60 mg/g, with an average value of 1.45 mg/g, with the highest value being No.11 and the lowest value being No.23. The coefficient of variation among varieties (lines) was 43.35%, and the difference was significant. The total acid content of different *Momordica charantia* varieties (lines) ranged from 0.31 to 0.52%, with an average value of 0.41%, with little difference among varieties (lines) and coefficient of variation of 12.20%.

1.2 Comparison of functional components in different varieties of *Momordica charantia*

1.2.1 Comparison of functional component content, variation amplitude and variation coefficient of different varieties of *Momordica charantia*

The contents of saponins in different varieties of *Momordica charantia* were significantly different (Table 3; Table 4), the average content was 5.02 μg /g, and the coefficient of variation was 45.62%. The saponins content of No.24 *Momordica charantia* was the highest (10.27 μg/g), and that of No.7 *Momordica charantia* was the lowest (1.97 μg/g), with a difference of more than five times. The content of polysaccharide in fruits of different varieties of *Momordica charantia* ranged from 23.49 to 60.01 mg/g, with an average content of 38.36 mg/g and a coefficient of variation of 25.47%. The highest content was No.21 and the lowest was No.9. The average flavonoid content in fruits of different varieties of *Momordica charantia* was 2.64 mg/g and the coefficient of variation was 21.97%. The highest flavonoid content was 4.11 mg/g in No.10 and 1.76 mg/g in No.20. The variation of total phenol content in *Momordica charantia* fruit ranged from 5.29 to 10.21 mg/g, the average content was 7.68 mg/g, and the coefficient of variation was 18.49%. The highest content was No.14, and the lowest content was No.1.

1.2.2 Distribution of saponins, polysaccharides, flavonoids and total phenols in different varieties of *Momordica charantia*

The saponins content in the flesh of 25 *Momordica charantia* varieties was approximately normal distribution, and the saponins content of 72.0% *Momordica charantia* varieties ranged from 1.96 to 6.75 μg/g. The distribution of polysaccharide content in flesh was approximately skewed, and the number of varieties in 23.49~45.61 mg/g accounted for 80% of the total number of varieties. The distribution of flavonoids in the flesh of *Momordica charantia* was also skewed, with about 80% of varieties distributed in 1.76~3.17 mg/g. The total phenol content in the flesh of *Momordica charantia* was approximately normal distribution, and about 60% varieties were distributed in 6.10~10.0 mg/g (Figure 1).

Table 1 Comparison of nutrient contents in pulp of 25 *Momordica charantia* varieties (lines)

No.	Vc content (μg/g)	Soluble protein content (mg/g)	Cellulose content (mg/g)	Amino acid content (mg/g)	Total acid content (%)
1	125.83±5.22b	6.07±0.02g	274.94±18.22b	0.52±0.04j	0.47±0.028b
2	73.43±3.20fg	8.65±0.10d	357.71±20.23b	0.73±0.023i	0.38±0.009c
3	82.29±1.88ef	9.91±0.31c	398.70±25.53a	2.00±0.038b	0.46±0.008b
4	62.35±2.33gh	5.02±0.22h	360.67±13.09b	1.68±0.013e	0.44±0.003b
5	79.17±4.67f	6.49±0.17f	282.13±10.25d	1.27±0.024f	0.48±0.010b
6	109.90±5.13cd	7.82±0.15e	299.93±9.88d	1.88±0.041d	0.46±0.007b
7	82.73±2.15ef	7.90±0.12e	349.86±7.26b	1.97±0.018c	0.47±0.016b
8	65.28±2.98g	6.20±0.08g	318.35±6.22c	1.86±0.013d	0.52±0.021a
9	63.07±3.21gh	13.30±0.40a	287.31±10.67d	2.03±0.012bc	0.42±0.005bc
10	158.65±4.33a	11.52±0.25b	317.30±16.30c	2.06±.0.042bc	0.44±0.003b
11	74.94±2.45f	7.85±0.33e	303.88±18.23cd	2.60±0.025a	0.48±0.027b
12	88.59±4.67e	10.71±0.24bc	308.78±15.56cd	1.25±0.040f	0.41±0.009bc
13	87.37±4.09e	7.58±0.34e	301.64±10.32cd	1.95±0.051c	0.41±0.026bc
14	56.65±2.56h	5.13±0.11h	399.46±17.89a	2.03±0.048bc	0.40±0.008bc
15	117.28±3.66b	4.70±0.06h	298.79±10.65d	1.05±0.043g	0.41±0.017bc
16	77.78±1.54f	8.38±0.13d	262.28±9.24e	2.14±0.027b	0.40±0.013bc
17	85.23±2.33e	6.35±0.15f	344.20±8.57bc	1.66±0.058e	0.41±0.003bc
18	64.53±1.36g	6.99±0.20f	315.73±5.33c	0.88±0.010h	0.40±0.028bc
19	75.85±3.22f	7.27±0.16ef	323.63±10.98c	0.88±0.012h	0.33±0.012cd
20	72.20±4.08fg	12.74±0.09a	311.26±10.20cd	1.03±0.017g	0.37±0.022c
21	64.18±2.78g	6.44±0.07f	315.54±9.87c	0.97±0.026g	0.34±0.006cd
22	83.24±2.33ef	6.75±0.12f	284.65±9.13d	0.86±0.015h	0.36±0.009c
23	102.74±3.98d	10.85±0.23bc	304.16±10.75cd	0.31±0.008k	0.34±0.009cd
24	121.19±7.22b	8.10±0.22de	299.40±5.99d	0.62±0.012j	0.31±0.027d
25	68.26±3.56g	6.89±0.16f	355.76±10.55b	2.14±0.013b	0.37±0.022c

Note: The value marked by different letters are significantly different (P<0.05)

Table 2 Variation range and coefficient of variation of nutrient content of 25 *Momordica charantia* varieties (lines)

Nutrient content	Range	Mean	Standard deviation	CV (%)
Vc content (μg/g)	56.65~158.65	85.71	24.40	28.47
Soluble protein content (mg/g)	4.70~13.30	7.98	2.32	29.07
Cellulose content (mg/g)	262.28~399.46	319.04	35.25	11.05
Amino acid content (mg/g)	0.31~2.60	1.45	0.63	43.45
Total acid content (%)	0.31~0.52	0.41	0.05	12.20

1.3 Comparison of antioxidant capacity of different varieties (lines) of *Momordica charantia*

There were significant differences in the total antioxidant capacity of different *Momordica charantia* varieties (lines) (Table 5; Table 6). The antioxidant capacity of DPPH, $ABTS^{+\cdot}$ and FRAP in pulp of *Momordica charantia* were significantly different among different varieties (lines) (P<0.05). The DPPH antioxidant values of the 25 cultivars ranged from 1.25 to 2.59 μmol Trolox/g, with an average value of 1.73 μmol Trolox/g, and the coefficient of variation was 19.65%. Among them, the DPPH antioxidant capacity was the strongest in No.22, and the weakest in No.6. The $ABTS^{+\cdot}$ antioxidant values of 25 varieties (lines) ranged from 40.36 to 92.89 μmol Trolox/g, the mean value was 67.38 μmol Trolox/g, and the coefficient of variation was 17.25%. The highest $ABTS^{+\cdot}$ antioxidant capacity was No.14, and the lowest was No.1. The FRAP antioxidant value of 25 varieties (lines) ranged from 5.26 to 21.42 μmol Trolox/g, with an average value of 11.62 and a coefficient of variation of

31.50%. The FRAP antioxidant capacity was highest in No.14 and lowest in No.22.

Table 3 Comparison of saponins, polysaccharides, flavonoids and total phenolic content in different *Momordica charantia* varieties

No.	Saponin content (μg/g)	Polysaccharide content (mg/g)	Flavonoid content (mg/g)	Total phenolic content (mg/g)
1	3.31±0.021gh	36.34±2.33cd	2.52±0.031d	5.29±0.025j
2	3.33±0.032gh	24.96±3.13e	3.20±0.021bc	9.33±0.145b
3	2.18±0.017i	27.42±1.63de	2.98±0.023c	8.00±0.036de
4	3.86±0.041g	39.02±2.51c	3.17±0.029bc	9.90±0.132a
5	2.90±0.023gh	29.04±1.13d	2.27±0.042e	7.89±0.039e
6	3.38±0.027gh	43.09±2.43c	2.96±0.039c	9.58±0.056b
7	1.97±0.011i	26.37±1.43de	3.27±0.017bc	7.91±0.008e
8	5.19±0.031e	32.72±2.03d	3.03±0.019c	9.18±0.075b
9	3.10±0.046gh	23.49±2.23e	2.93±0.045c	7.53±0.018f
10	9.15±0.035b	40.77±3.43c	4.11±0.041a	8.76±0.037c
11	9.34±0.029b	38.29±3.63c	2.25±0.012e	6.56±0.059g
12	3.85±0.029g	33.84±1.93cd	1.83±0.023f	8.08±0.152de
13	4.34±0.032fg	28.21±1.62d	2.37±0.035de	7.60±0.092f
14	5.25±0.051e	31.26±2.11d	3.66±0.026b	10.21±0.105a
15	5.68±0.043e	36.69±4.13cd	2.06±0.013e	8.39±0.003d
16	3.02±0.018h	39.42±3.33c	2.57±0.019d	7.44±0.004f
17	3.00±0.042h	40.47±4.41c	1.88±0.009f	5.85±0.073i
18	6.82 0.055d	35.56±3.61cd	2.52±0.011d	9.11±0.097b
19	6.04±0.036de	43.65±1.89c	2.96±0.014c	6.92±0.089g
20	6.33±0.043d	58.84±5.23a	1.76±0.024f	6.58±0.095g
21	7.62±0.025c	60.01±5.16a	2.23±0.023de	6.18±0.005h
22	3.92±0.030g	48.67±1.33b	2.60±0.028d	5.50±0.026i
23	4.97±0.027ef	42.79±2.24c	2.48±0.017d	7.82±0.061e
24	10.27±0.037a	46.04±2.03bc	2.23±0.013de	6.77±0.035g
25	6.66±0.034d	51.95±3.43ab	2.12±0.029e	5.67±0.029i

Note: The value marked by different letters are significantly different (P<0.05)

Table 4 Variation range and coefficient of variation of saponins, polysaccharides, flavonoids and total phenolic content in different varieties of *Momordica charantia*

Functional components	Range (μg/g)	Mean (mg/g)	Standard deviation	CV (%)
Saponin content	1.97~10.27	5.02	2.29	45.62
Polysaccharide content	23.49~60.01	38.36	9.77	25.47
Flavonoid content	1.76~4.11	2.64	0.58	21.97
Total phenolic content	5.29~10.21	7.68	1.42	18.49

1.4 Correlation analysis between functional component content and total antioxidant capacity of *Momordica charantia*

There was no significant positive correlation between saponin content and antioxidant capacity of DPPH in *Momordica charantia*, but no significant negative correlation between saponin content and antioxidant capacity of $ABTS^{+\cdot}$ and FRAP. Polysaccharide content was not significantly positively correlated with the antioxidant capacity of DPPH, was not significantly positively correlated with the antioxidant capacity of $ABTS^{+\cdot}$ and was significantly negatively correlated with the antioxidant capacity of FRAP (r=-0.581, P<0.05). There was no significant negative correlation between flavonoid content and antioxidant capacity of DPPH in *Momordica charantia*, but no significant positive correlation between flavonoid content and antioxidant capacity of ABTS and FRAP. The total phenol content in the flesh of *Momordica charantia* was significantly correlated with the three kinds of antioxidant capacity, and was significantly negatively correlated with the antioxidant capacity of DPPH (r=-0.436, P<0.05), and was significantly positively correlated with the antioxidant capacity of $ABTS^{+\cdot}$ (r=0.795, P<0.01). It was positively correlated with the antioxidant capacity of FRAP (r=0.853, P<0.01) (Table 7).

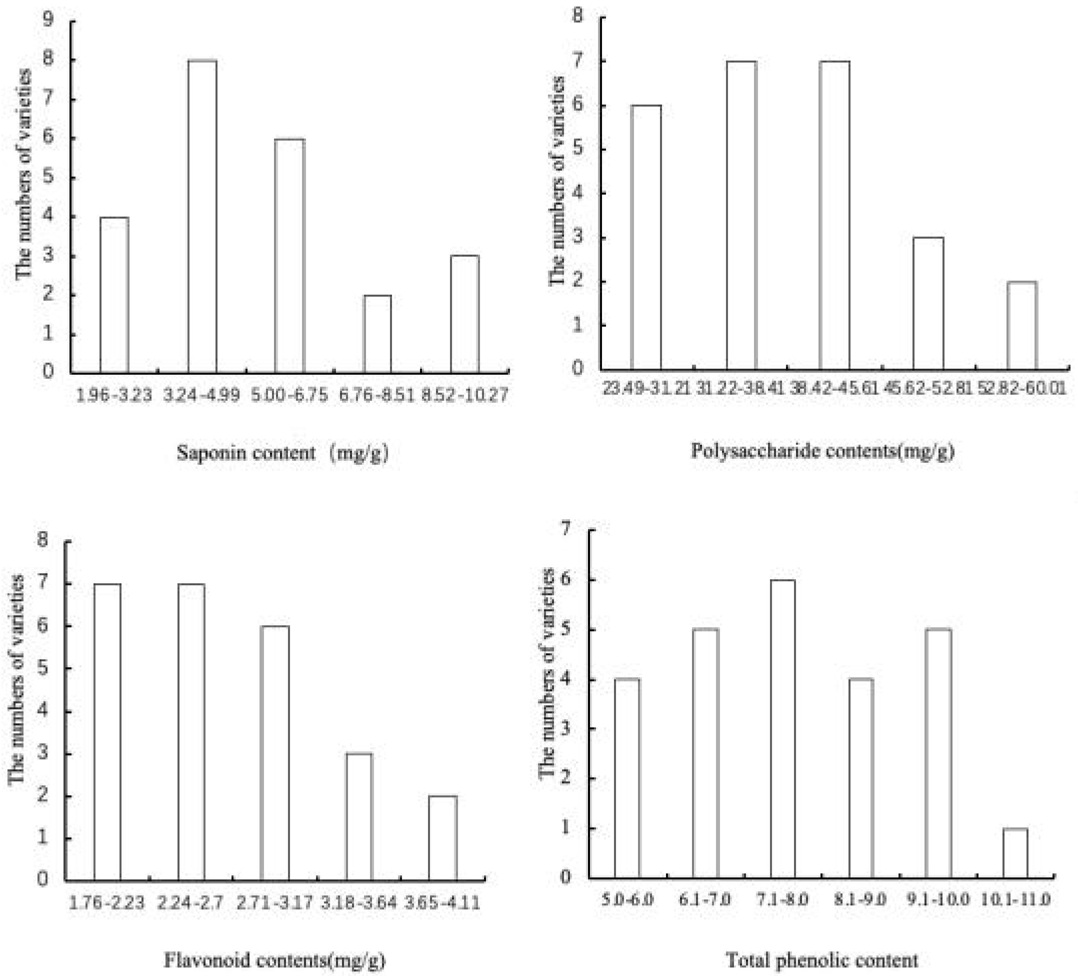

Figure 1 Variety distribution of saponins, polysaccharides, flavonoids and total phenolic content in *Momordica charantia*

2 Discussion

As a vegetable with the same origin as medicine and food, *Momordica charantia* has attracted more and more people's attention and love (Du et al., 2014, Chinese Agricultural Science Bulletin, 30(1): 226-231). A large number of studies have shown that different varieties and different habitats have a great impact on the nutritional quality of *Momordica charantia* (Xiang et al., 2000; Zhang et al., 2011; Jie et al., 2011). Du et al. (2014, Chinese Agricultural Science Bulletin, 30(1): 226-231) found that there were great differences in the nutritional composition of 22 different varieties (lines) of *Momordica charantia*. The average Vc content, cellulose content and titratable acid content were 8.34 mg/(100 g·FW), 2.33% and 10.24 mmol/(100 g·FW), respectively. Li et al. (2007) determined that the protein content of fresh *Momordica charantia* in the three producing areas was similar, and the Vc content was greatly affected by the producing area. In this study, the nutrient content of fresh *Momordica charantia* pulp of 25 varieties (systems) was determined. The nutrient content of different varieties (systems) was significantly different. The average contents of Vc, soluble protein, cellulose, amino acid and total acid were 85.71 μg/g, 7.98 mg/g, 319.04 mg/g, 1.45 mg/g and 0.41%, respectively. The average content of Vc was similar to that of Du et al. (2014, Chinese Agricultural Science Bulletin, 30(1): 226-231) showed similar results. The variation range of each nutrient component was large, and the coefficient of variation of amino acid content was the largest, which was 43.35%, followed by soluble protein content and Vc content, which were 29.07% and 28.47% respectively, which was consistent with the results of previous studies (Li et al., 2007; Zhang et al., 2011). As a fresh vegetable, *Momordica charantia* requires high content of Vc, soluble protein and amino acid, while low content of cellulose and total acid. After comprehensive comparison of 25 *Momordica charantia* varieties (lines), variety 10 *Momordica charantia* has the highest Vc content, low total acid and cellulose content. As a type of white *Momordica charantia*, bitter taste is moderate and crisp. Secondly, the varieties (lines) with higher Vc content were No.1, No.6, No.15, No.23 and No.24, which were suitable for cultivation as fresh edible vegetables.

Table 5 Total antioxidant capacity of different varieties of *Momordica charantia*

No.	DPPH antioxidant value (μmol Trolox/g)	DPPH antioxidant value (μmol Trolox/g)	DPPH antioxidant value (μmol Trolox/g)
1	2.08±0.086b	40.36±3.27j	8.59±0.10f
2	1.37±0.021g	70.98±2.64def	12.71±0.17c
3	1.72±0.004d	70.89±3.09def	11.66±0.12d
4	1.68±0.077de	90.26±0.02ab	15.26±0.31b
5	1.58±0.103f	74.46±2.14cde	10.54±0.17e
6	1.25±0.045h	76.97±4.56cd	13.09±0.21bc
7	1.53±0.113f	83.55±1.99bc	14.62±0.20b
8	1.32±0.069g	71.26±1.18def	12.87±0.16c
9	1.53±0.071f	58.48±2.65gh	12.24±0.13cd
10	2.36±0.039a	69.66±2.05def	15.62±0.18b
11	1.63±0.043de	57.25±1.53gh	11.14±0.16de
12	1.30±0.097g	66.07±1.38efg	14.77±0.22b
13	1.89±0.143c	61.45±1.19fgh	12.35±0.15cd
14	1.40±0.046g	92.89±3.70a	21.42±0.31a
15	2.17±0.102b	74.25±4.57cde	14.90±0.20b
16	1.76±0.064d	70.56±4.58def	13.09±0.19bc
17	1.60±0.103de	60.42±2.28fgh	6.19±0.07h
18	1.75±0.041d	64.94±3.44efg	13.10±0.15bc
19	1.74±0.113d	74.42±1.86cdw	10.73±0.15e
20	1.37±0.103g	62.03±3.08fgh	7.42±0.08fg
21	1.95±0.134c	53.78±1.87ghi	7.19±0.12g
22	2.59±0.099a	55.22±1.94ghi	5.26±0.05i
23	2.09±0.150b	66.16±0.65efg	10.85±0.11e
24	1.71±0.126d	56.99±1.91ghi	8.47±0.06f
25	2.00±0.064bc	61.24±2.13fgh	6.48±0.08h

Note: The value marked by different letters are significantly different (P<0.05)

Table 6 Variation range and coefficient of variation of antioxidant capacity in different varieties of *Momordica charantia*

Total antioxidant capacity	Range (μmol Trolox/g)	Mean (μmol Trolox/g)	Standard deviation	CV (%)
DPPH antioxidant value	1.25~2.59	1.73	0.34	19.65
$ABTS^{+\cdot}$ antioxidant value	40.36~92.89	67.38	11.62	17.25
FRAP antioxidant value	5.25~21.42	11.62	3.66	31.50

Table 7 Correlation between content of functional components and total antioxidant capacity in *Momordica charantia* fruit

Functional components	DPPH	$ABTS^{+\cdot}$	FRAP
Saponin content	0.284	-0.294	-0.126
Polysaccharide content	0.377	-0.387	-0.581^{*}
Flavonoid content	-0.267	0.231	0.353
Total phenolic content	-0.436^{*}	0.795^{**}	0.853^{**}

Note: *: Indicates significant correlation at 0.05 level; **: Indicates significant correlation at 0.01 level

Saponins, polysaccharides, flavonoids and total phenols are the main functional components of momordica balmomordica, which have various physiological activities such as lowering blood sugar, reducing weight, antioxidant, clearing heat and detoxifying. The content of functional components in different varieties of *Momordica charantia* was also different (Tian et al., 2008; Huang et al., 2008; Zhang et al., 2016; Yang et al., 2009; Jiang et al., 2020). Liu et al. (2017) compared the content of saponins in pulp of 13 different varieties of

Momordica charantia, and the range was 0.52~1.20 g/100g DW, with an average value of 0.79 g/100g DW. Cao et al. (2014) determined the polysaccharide and saponin contents of 41 *Momordica charantia* varieties, and the polysaccharide contents ranged from 5.24 to 92.40 mg/g, and the saponin contents ranged from 5.21 to 52.21 mg/g. Huang et al. (2011) compared the different contents of total phenol and total flavone among 14 *Momordica charantia* varieties, and the total phenol ranged from 175.27 to 413.79 mg GAE/100 g DW, with an average value of 292.96 mg GAE/100 g DW, and the coefficient of variation was 22.10%. Flavonoid content ranged from 8.97 to 18.22 mg CE/100 g DW, with an average value of 11.73 mg CE/100 g DW, and the coefficient of variation was 22.80%. In this study, the contents of saponins, polysaccharides, flavonoids and total phenols in the flesh of 25 different varieties (lines) of *Momordica charantia* showed significant differences, and the variation was also large, with an average value of 5.02 μg/g, 38.36 mg/g, 2.64 mg/g and 7.68 mg/g, respectively. The average content of saponins was slightly lower than that of Liu et al. (2017), but higher than that of Cao et al. (2014) and Jiang et al. (2020). The variation of polysaccharide content was less than that determined by Cao et al. (2014), and the mean contents of flavonoids and total phenols were higher than those determined by Huang et al. (2011). Among the four functional components, saponin content had the highest coefficient of variation (45.62%), while total phenol content had a smaller coefficient of variation (18.49%). In conclusion, the content of functional components in the pulp of *Momordica charantia* was greatly affected by regional, variety, environment and other factors. Among the 25 varieties (lines), the varieties (lines) with the highest contents of saponins, polysaccharides, flavonoids and total phenols were No.24, No.21, No.10 and No.14, respectively, which could be cultivated as special varieties for processing.

Antioxidant activity is an important physiological activity of *Momordica charantia*, which is closely related to functional components of *Momordica charantia* (Huang et al., 2011; Yuan et al., 2006; Cao et al., 2014; Liu et al., 2017). The antioxidant capacity of different varieties of *Momordica charantia* was different. Liu et al. (2017) found that the total antioxidant capacity index of total saponins of 13 different varieties of *Momordica charantia* ranged from 2 747.46 to 15 584.07 μmol Trolox/g, with an average of 8 879.48 μmol Trolox/g, and the coefficient of variation was 34.91%. The total saponins were not the main contributors to antioxidant activity of *Momordica charantia*. Huang et al. (2011) evaluated the antioxidant capacity of *Momordica charantia* samples by using FRAP method, DPPH and IC50 value of $ABTS^{+\cdot}$ scavenging capacity. The ranges were 272.16~713.32 mg TE/100g DW, 11.43~34.14 mg GAE/100 g DW, and 21.57~119.71 mg GAE/100 g DW, respectively, which fully reflected the antioxidant effects of the samples. Total phenol content was positively correlated with FRAP value and negatively correlated with IC50 value of $ABTS^{+\cdot}$ scavenging ability and DPPH, respectively. In this study, DPPH method, $ABTS^{+\cdot}$ method and FRAP method were used to study the antioxidant capacity of 25 varieties (lines). The antioxidant values ranged from 1.25 to 2.59 μmol Trolox/g, 40.36 to 92.89 μmol Trolox/g, 5.25 to 21.42 μmol Trolox/g, and the coefficients of variation were 19.65%, 17.25% and 31.50%, respectively. The antioxidant capacity of pulp was much lower than that of total saponins and phenols of extracts (Huang et al., 2011; Liu et al., 2017), which is also the main reason for developing industrial extraction methods of functional components of *Momordica charantia* and processing them into various health products. In this study, the contents of total saponins and flavonoids were not significantly correlated with the antioxidant capacity of *Momordica charantia* pulp, while polysaccharide content was negatively correlated with the antioxidant capacity of FRAP (r=0.581, P<0.05), and total phenol content was significantly correlated with the three antioxidant capacities. It was significantly negatively correlated with the antioxidant capacity of DPPH (r=-0.436, P<0.05), and significantly positively correlated with the antioxidant capacity of ABTS and FRAP (r=0.795, P<0.01; r=0.853, P<0.01), which was consistent with the findings of Huang et al. (2011), Du et al. (2009), and Kriengsak et al. (2006). The results showed that the total phenol content in the pulp of *Momordica charantia* was closely related to the antioxidant capacity of *Momordica charantia*, indicating that the total phenol was one of the important contributions to the antioxidant capacity of *Momordica charantia*.

There were significant genotypic differences in the contents of nutrients, functional components and antioxidant values in the pulp of 25 *Momordica charantia* varieties (lines), and the total phenolic content in the pulp was the main contribution of antioxidant activity of *Momordica charantia*. In the breeding and cultivation of new varieties of *Momordica charantia*, fresh food and medicinal processing varieties should be distinguished, and corresponding varieties should be selected according to different uses, which is conducive to giving full play to the advantages of varieties and commercial value.

3 Materials and Methods

3.1 Test materials

The 25 bitter melon materials used in this experiment were provided by the research group of Horticulture Institute of Shanghai Academy of Agricultural Sciences engaged in the breeding of bitter melon varieties (Table 8), among which 'Qingqiu No.1' was the self-bred variety, 'Taiwanqingpi', 'Abao No.3', 'Fujian', 'Yuezhen', 'Pingguo', 'Baiyu' and 'Jufengcuilv' were purchased hybrids, and the remaining 17 were breeding hybrids.

Table 8 Basic fruit characters of 25 *Momordica charantia* varieties (lines)

No.	Varieties	Types
1	K0909-1	Dark green strip tumor long *M.charantia*
2	K0909-2	Dark green strip tumor long *M.charantia*
3	Taiwanqingpi	Green strip tumor long *M.charantia*
4	K1701	White green grain tumor long *M.charantia*
5	K1802	Green strip tumor long *M.charantia*
6	K1703	White green grain tumor long *M.charantia*
7	Abao No.3	Green strip tumor long *M.charantia*
8	Fujian	Green grain tumor long *M.charantia*
9	K1608	Green strip tumor long *M.charantia*
10	K1309	Green strip tumor long *M.charantia*
11	K1103	White strip tumor and warty long *M. charantia*
12	Qingcui No.1	Light green strip tumor and warty long *M. charantia*
13	K1902	Green strip tumor and warty long *M.charantia*
14	K1921	Green strip tumor and warty long *M.charantia*
15	Yuezhen	White grain tumor short *M. charantia*
16	Pingguo	White grain tumor short *M. charantia*
17	Baiyu	White grain tumor long *M. charantia*
18	K1102	Green strip tumor and warty long *M.charantia*
19	K1107	White strip tumor and warty long *M.charantia*
20	K1702	Green strip tumor long *M.charantia*
21	K0806	Green strip tumor long *M.charantia*
22	K0802	Green grain tumor short *M. charantia*
23	K1303	Green strip tumor and warty long *M.charantia*
24	K1316	Light green strip tumor and warty long *M.charantia*
25	Jufengcuilv	Green strip tumor and warty long *M.charantia*

3.2 Test methods

The experiment was conducted at Zhuanghang Comprehensive Test Station of Shanghai Academy of Agricultural Sciences. On February 25, 2020, plump seeds of each *Momordica charantia* variety were selected and soaked for 15 h, then seeds were artificially consumed, and then placed in an incubator at 30 °C to promote germination. When the buds were 0.5 cm long, they were sown in 50 hole trays, and the seedbed temperature was set at 30 °C. On March 17, the seedlings with 2 leaves and 1 heart were planted in the greenhouse with a plant spacing of 45 cm and a row spacing of 1 m. The climbing net was used to build an arch frame. Field management of all varieties is basically unified. The middle and upper female flowers were selected for pollination in the morning on the day of flowering. After pollination, the pollination date was marked with a label. 18 d after pollination, perfectly good commercial *Momordica charantia* fruits free of pests and diseases were selected and brought back to the laboratory, the flesh was cut, removed and seeded, and the middle flesh was selected, part of the fruit was dried in a 65 °C oven for use, and the other part was stored in a -40 °C refrigerator for use. Fruits from 6 plants of each variety were mixed and sampled.

3.3 Test items and methods

3.3.1 Determination of nutrient content

The nutrient content was determined by the kit of Suzhou Comin Biotechnology Co., LTD.: Vitamin C reacted with solid blue salt B in acetic acid solution to form yellow oxalhydrazid-2-hydroxybutyllactone derivatives, and the absorbance was determined at the maximum absorption wavelength of 420 nm. Soluble protein content was determined by Coomassie blue staining G-250 staining. Cellulose is heated and decomposed into β-glucose under acidic conditions. β-glucose can be dehydrated to produce β-furfural compounds under the action of strong acid. β-furfural compounds can be dehydrated and condensed with anthrone to produce furfural derivatives. The content of free amino acid was determined by the colorimetry of ninhydrin solution. Titrable acid content was determined by acid-base neutralization titration.

3.3.2 Determination of functional component content

The contents of saponins, polysaccharides, flavonoids and total phenols were determined by dried *Momordica charantia* and fruit jerky samples. The kits were purchased from Suzhou Comin Biotechnology Co., LTD. The saponins were extracted by ultrasonic wave, and the total saponins were determined by vanillin - perchloric acid chromogenic system. Polysaccharide was extracted by water purification and precipitation method, and the total polysaccharide content was determined by phenol-sulfuric acid method. Flavonoid content was determined by $AL(NO_3)_3$-$NaNO_2$ complex method. In alkaline nitrite solution, flavonoid and aluminum ions formed a red complex with characteristic absorption peak at 510 nm. Flavonoid content of sample can be calculated by measuring the absorbance value of sample extract at 510 nm. Phenols are reduced by tungstate molybdate under alkaline conditions to produce blue compounds, which have characteristic absorption peaks at 760 nm. The total phenolic content of the sample can be obtained by measuring the absorption value at 760 nm.

3.3.3 Determination of total antioxidant capacity

The total antioxidant capacity of *Momordica charantia* pulp was determined by the kit of Suzhou Comin Biotechnology Co., LTD. Determination of the antioxidant capacity of FRAP (Ferric reducing/antioxidant power). The ability of the antioxidant to reduce Fe^{3+} -tripyridine triazine ((Fe^{3+}-TPTZ)) to produce blue Fe^{2+}-TPTZ in an acidic environment reflects the total antioxidant capacity. The sample solution was thoroughly mixed with the working solution for 20 min, and the absorption value of 593 nm was determined. The total antioxidant capacity of the sample was expressed by the amount of antioxidant Trolox obtained from the standard curve. $ABTS^{+\cdot}$ (2,2 '-diazo-di-3-ethylbenzothiazolin-6-sulfonic acid, 2,2' -azinobis-3-ethylbenzothiazoline 6-sulphonic acid diammonium salt) determination of antioxidant capacity. When $ABTS^{+\cdot}$ solution is added into the sample solution, the antioxidant components in the sample solution can react with $ABTS^{+\cdot}$ and make the reaction system fade. Changes in absorbance were measured at 734 nm, and the antioxidant capacity of the antioxidants was quantified using Trolox as a control system. Determination of antioxidant capacity of DPPH (1, 1-diphenyl-2-Picrylhydrazine radical,1,1-diphenyl-2-picrylhydrazy). DPPH is a stable free radical, soluble in polar solvents such as methanol and ethanol, with maximum absorption at 515 nm. A decolorization reaction occurs when antioxidants are added to DPPH solution, so changes in absorbance can be used to quantify the antioxidant capacity of the antioxidants using Trolox as a control system. All three antioxidant capacities were measured in μmol Trolox/g fresh weight.

3.4 Data processing

EXEL and SPSS19.0 were used for data processing and analysis. The contents of saponins, polysaccharides, flavonoids and total phenols in *Momordica charantia* were distributed according to (Maximum - Minimum)/N. The histogram was made, and the percentage of the number of varieties in the total sample was calculated. Bivariate correlation analysis was performed between functional components and antioxidant capacity of *Momordica charantia*, and differences among varieties were compared by Tukey method.

Authors' contributions

ZHM and DXT participated in the experimental design; ZHM conducted data analysis and paper writing; JHJ, YJZ, HLZ and CJW participated in the experimental design and result analysis. DXT made the final revision of the paper. All authors read and approved the final manuscript.

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References

Cao J.J., Xu L.S., Shen J.X., Yu J.L., and Zhu P., 2014, Differences in contents of polysaccharide and saponin among different varieties of Momordica charantia L. and its optimal harvesting period, Hunan Nongye Kexue (Hunan Agricultural Sciences), (2): 63-66.

Du G.R., Li M. J., Ma F. W., and Liang D., 2009, Antioxidant capacity and the relationship with polyphenol and vitamin C in Actinidia fruits, Food Chemistry, 113(2): 557-562.
https://doi.org/10.1016/j.foodchem.2008.08.025

Huang J., Zhang M.W., Zhang R.F., Zhang Y., Wei Z.C., Xin X.F., Chi J.W., and Tang X.J., 2008, Comparison of polysaccharide content in different cultivars of Momordica charantia L. and in different tissues and development stages, Yuanyi Xuebao (Acta Horticulturae Sinica), 35(5): 757-760.

Huang L., Deng Y.Y., Zhang M. W., Zhang Y., Wei Z.C., Zhang R.F., and Tang X.J., 2011, Phenolic profiles and antioxidant activity of Momordica charantia L. of different varieties, Zhongguo Nongye Kexue (Scientia Agricultura Sinica), 44(22): 4660-4668.

Jiang D., Li G.G., Zhu W.B., Yuan Y., Zheng Y.S., 2020, Analysis of differences in nutritional components and saponin contents of different bitter gourd types, Zhongguo Guacai (China Cucurbits and Vegetables), 33(6): 34-40.

Jie M.H., Zhang J.S., and Jie J.M., 2001, Relationships between some physio-biochemical changes and senescence during storage in bitter gourd, Xibei Zhiwu Xuebao (Acta Bot. Boral.-Occident. Sin.), 24(4): 716-719.

Keller A.C., Ma J., Kavalier A., He C., and Kennelly E.J., 2011, Saponins from the traditional medicinal plant Momordica charantia stimulate insulin secretion in vitro, Phytomedicine, 19(1): 32-37.
https://doi.org/10.1016/j.phymed.2011.06.019
PMid:22133295 PMCid:PMC3389550

Kriengsak T., Unaroj B., Kevin C., Luis C.Z., and David H.B., 2006, Comparison of ABTS+·, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts, Food Composition and Analysis, 19: 669-675.
https://doi.org/10.1016/j.jfca.2006.01.003

Li D.Y., Zhou Y., and Ye M.J., 2007, Different habitat balsam pear nutrition ingredient analysis, Weiliang Yuansu Yu Jiangkang Yanjiu (Studies of Trace Elements and Health), 24(5): 29-37.

Lin K.W., Yang S.C., and Lin C.N., 2011, Antioxidant constituents from the stems and fruits of Momordica charantia , Food Chem., 127(2): 609-614.
https://doi.org/10.1016/j.foodchem.2011.01.051
PMid:23140707

Liu H.J., Zhang M.W., Zhang R.F., Zhang Y., Wei Z.C., Ma Y.X., Liu L., and Deng Y.Y., 2017, Saponin profiles and antioxidant activity, α-glucosidase inhibitory activity of Momordica charantia of different varieties, Zhongguo Nongye Kexue(Scientia Agricultura Sinica), 50(17): 3413-3421.

Luo J., and Zhang J., 2016, Research progress on application value and development of balsam pear, Shipin Gongye (The Food Industry), 37(10): 243-246.

Tian L.D., Zhang M. W., Guo S.Y., Zhang R.F., Chi J.W., Wei Z.C., Zhang Y., and Tang X.J., 2008, Comparison of saponin contents of different varieties of Momordica charantia L. and their inhibition on α-glucosidase activity, Zhongguo Nongye Kexue(Scientia Agricultura Sinica), 41(10):3415-3421.

Xiang C.P., Wu Y.C., and Wang L.P., 2000, Analysis and utilization of nutrient composition in bitter gourd, Huazhong Nongye Daxue Xuebao (Journal of Huazhong Agricultural University), 19(4): 388-390.

Yang E.C., Zhang Y.J., and Wang Q.L., 2009, Research progresses of the effective components and functions of Momordica charantia L., Hebei Nongye Kexue (Journal of Hebei Agricultural Sciences), 13(1): 162-164.

Yuan Z.H., Su J.W., Hu X.J., and Li Y.Q., 2006, Research Progress on nutritional chemical components and health function of Momordica charantia L., Hunan Nongye Kexue (Hunan Agricultural Sciences), (5): 48-50.

Zhang D., Xiang C.P., Li J. L., and Kong L.W., 2010, Comparative analysis of polysaccharides and composition in bitter melon inbreed lines, Yuanyi Xuebao (Acta Horticulturae Sinica), 37(7): 1169-1174.

Zhang F.Y., Chen C.Y., Hu Z.H., Lei G., and Wu Z.L., 2011, Analysis on the diversity of morphological traits and nutritional contents in bitter gourd germplasm resources, Zhongguo Nongxue Tongbao (Chinese Agricultural Science Bulletin), 27(4): 183-188.

ZhangW.J., Huang Y.Z., Lin Y.S., and Zhang Y.C., 2016, Comparative analysis of saponin contents in different parts of bitter gourds of twenty-nine varieties, Fujian Nongye Xuebao (Fujian Journal of Agricultural Sciences), 31(6): 599-603.