The berries on the top

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Abstract (200 words max)

BACKGROUND: Berries are important sources of crucial dietary components (such as vitamins and minerals), as well as various phytonutrients that may be potentially beneficial to human health and could be used against chronic diseases including cancer and cardiovascular disorders.

OBJECTIVE: The current study aimed to identify and analyze the 100 most cited papers related to berry research.

METHODS: The Scopus database was searched to extract data. Two of the authors independently evaluated the manuscripts for relevance. Bibliometric data, including citation count, were analyzed together with the words in the titles and abstracts of the 100 most cited berry-related papers.

RESULTS: Seventy-two of the 100 most cited papers were research articles. Most of them were published during the 2000s, and related to subject areas of agricultural and biological sciences (n = 64), biochemistry, genetics and molecular biology (n = 35), chemistry (n = 29), medicine (n = 24), and nursing (n = 10). *Journal of Agricultural and Food Chemistry* was the dominating choice of publication outlet (n = 26).

CONCLUSIONS: Antioxidant and anticancer benefits appeared to be the major subject terms. Berries that were mentioned in at least 10% of the 100 papers were strawberry, blueberry, cranberry, raspberry, blackberry, bilberry, and grape berry. The review could provide a valuable guide for designing future studies.

Keywords: antioxidant; berry; bibliometrics; chemistry; citation classic; food science.

1. Introduction

Berries contain not only crucial dietary components such as vitamins and minerals, but also a wide range of phytonutrients that may be potentially beneficial to human health [1] and could be used against chronic diseases including cancer and heart disorders [2]. For instance, the consumption of berry may enhance the human liver function in terms of reducing the alanine aminotransferase (ALAT) values [3], increasing high-density lipoprotein (HDL) cholesterol, and reducing blood pressure, all of which could help reduce systemic inflammation and risk of cardiovascular and metabolic diseases [4]. For example, it was reported that dietary consumption of strawberry could increase the plasma antioxidant capacity [5]. There have been numerous comprehensive reviews on the phenolic contents of berries, including from phenolic acids, tannins, lignans, stilbenes, and flavonoids [6], and their antioxidant, anticancer, anti-inflammatory as well as neuroprotective properties [7, 8].

Research on berries could be traced back as early as in the mid-18th century, according to Scopus literature database. Interestingly, the earliest publications seemed to focus on berry poisoning and associated deaths [9-11], instead of the current focus on the health benefits of consuming berries as introduced above. Undoubtedly, there have been numerous publications on berry ripening; the berry research field, after over two centuries of development, has literally ripened. It is worthwhile to identify the most impactful publications on berries and give a brief overview of them. Therefore, in the current study, we aimed to identify and analyze the 100 most cited papers on berries. Besides, we aimed to identify also the hot topics, prominent authors and countries contributing to these publications, and the most popular berries that were investigated in these publications. Last but not least, as multiple studies have indicated a higher journal impact factor as well as journal specialties would lead to an increased citation count [12-14], we tested if such association existed within the 100 most cited berry-related papers, and hypothesized that a positive correlation existed between the journal impact factor and the paper citation count (both total and adjusted counts).

2. Materials and methods

2.1. Data source

Bibliometric data were extracted from Scopus, an online multidisciplinary database. Upon a preliminary search, we have found that many of the highly cited papers involving the word "berry" were related to Berry's phase or Berry's conjecture which are the concepts used in physics, but certainly not related to the berry fruits. To systematically exclude these irrelevant papers, in September 2018, we searched Scopus to identify papers with the following string: TITLE-ABS-KEY ("berry" OR "berry*" OR "berries" OR "berries*") AND NOT ("berry's phase" OR "berry phase" OR "berry's conjecture" OR "berry conjecture" OR "berry's curvature" OR "berry curvature"). This string searched for papers that mentioned berry or berries in their titles, abstracts or keywords as fruits, but not Berry as a part of terms used in physics named after a scientist.

The identified papers were sorted out by citation count in descending order. Two of the authors (AWKY and AGA) independently evaluated the manuscripts for relevance and compiled the list of 100 most cited papers. We did not place any additional restrictions on the search, such as year of publication and other parameters.

2.2. Data extraction

The 100 most cited papers were evaluated and recorded for: (1) publication year; (2) journal title; (3) 2017 journal impact factor (released by Clarivate Analytics in Journal Citation Reports 2018); (4) total citation count; (5) adjusted citation count (i.e., citation count per year since publication); (6) authorship; and (7) manuscript type.

Meanwhile, Pearson's correlation tests were conducted in SPSS 25.0 (IBM, New York, USA) to evaluate if there existed a correlation between the citation counts (total / adjusted) of the 100 most cited papers and journal impact factor or number of authors. Test results with $p < 0.05$ were considered significant.

2.3. Term map

The software VOSviewer was utilized to extract and analyze words that appeared in the titles and abstracts of these 100 most cited papers [15], and visualize them with a bubble map. Each bubble represents a term or phrase. The bubble size indicates how often the word appeared among the 100 manuscripts (binary counting was used, which implied that multiple appearances in a single paper counted as one). The bubble color indicates the averaged citation count received by manuscripts involving the term. Two bubbles are nearer to each other if the two terms co-occurred in manuscripts more often. The term map visualizes terms that appeared in at least two of the 100 papers.

3. Results and discussion

The search resulted in 21,508 papers. The 100 most cited berry-related papers are listed in Table 1. They were mainly research articles (n = 72) and reviews (n = 21), with a few conference papers (n = 6) and a short survey (n = 1). All 100 papers were written in English, most of which published during the 2000s (Figure 1), and were related to subject areas of agricultural and biological sciences (n = 64), biochemistry, genetics and molecular biology (n = 35), chemistry (n = 29), medicine (n = 24), and nursing (n = 10). These 100 papers listed 1 to 17 authors (mean ± SD: 4.4 ± 3.2), and were published in journals with impact factor ranging from no impact factor value to 79.258 (mean ± SD: 4.882 ± 7.860).

3.1. Citation count

The citation count of these 100 papers ranged from 264 to 2,190 (mean ± SD: 454.1 ± 276.7). The adjusted citation count (i.e., citation count per year since publication) ranged from 10.7 to 155.4 (mean ± SD: 33.0 ± 22.6). In terms of total citation count, Kähkönen et al. published a top-ranked article that reported the antioxidant activity of plant extracts, containing phenolic compounds, which were particularly abundant in aronia and crowberry [16]. In terms of adjusted citation count, the top-ranked paper was a review, published by Del Rio et al. on availability and evidence of benefits of dietary polyphenolics such as anthocyanins from blueberries, blackberries and strawberries against chronic diseases [17].

[Table 1]

3.2. Major contributors

The papers were contributed by 160 authors, affiliated with 149 institutions distributed among 25 countries / territories. The five most prolific authors for the most cited papers were Simon P. Robinson from Commonwealth Scientific and Industrial Research Organisation (CSIRO) Plant Industry in Australia (n = 5); Herman Adlercreutz, Marina Heinonen from the University of Helsinki in Finland, Rune Blomhoff and Kari Holte from the University of Oslo in Norway, Navindra P. Seeram from the University of Rhode Island in the United States, and Bharat B. Aggarwal right now from the Inflammation Research Center in the United States of America (each n = 4, equally ranked second).

The five most prolific institutions were the University of Helsinki (n = 15), the United States Department of Agriculture (USDA, n = 6), the University of Eastern Finland (n = 6), Cooperative Research Centre for Viticulture (Australia, n = 5), and Agriculture and Agri-Food Canada (n = 5). The United States of America has contributed to 38 of these 100 papers, followed by Finland (n = 20), Australia (n = 9), Canada (n = 8), and Japan (n = 6). Perhaps unsurprisingly, the dominance of the United States of America was similar to other research fields such as neuroimaging [18], public health [19], general neuroscience [20-22], and nutritional neuroscience [23]. This could be potentially explained by the large amount of money invested by private sector into research and development, as well as the large number of PhD students and full-time researchers in the nation [24]. Here in berry research, however, the contribution by Finland was significantly higher than its contribution to the highly cited manuscripts dealing with related fields such as ethnopharmacology [25], and nutraceuticals and functional foods [26]. In fact, berries were identified as important sources of flavonoid intake for Finnish people [27]. This might have hinted an ethnobotanical reason, which is worth to be further investigated. Regarding journals, *Journal of Agricultural and Food Chemistry* was the dominating choice of publication outlet (n = 26), followed by *American Journal of Enology and Viticulture* (n = 6). The rest of the journals have each contributed to less than 5% of the 100 most cited berry-related papers. Such dominance by a single most prolific journal is similar to the situation of the 100 most cited papers in ethnopharmacology (*Journal of Ethnopharmacology*, 17%) [25] but not in nutraceuticals and functional foods [26].

3.3. Relationship between citation count and author number or journal impact factor

Total citation count and adjusted citation count did not have significant correlation with author number (r = 0.031, $p = 0.760$; r = 0.135, $p = 0.181$) or journal impact factor (r = -0.073, $p = 0.469$; r = -0.065, $p = 0.522$). Meanwhile, total citation count was positively correlated with adjusted citation count (r = 0.695, $p < 0.001$).

3.4. Term map

A term map was generated to visualize the words in the titles and abstracts of the 100 papers. There were 731 terms that appeared in two or more of the 100 papers, covering various basic science aspects such as antioxidant and angiogenesis, which in turn might influence carcinogenesis and some chronic diseases (Figure 2). These foci seemed to have formed the cornerstones of the most cited berry research. Several molecules have 500+ citations per manuscript (Figure 3), namely trihydroxystilbene (n = 2, citations per paper = 737), isoflavonoid glycoside (n = 3, citations per paper = 704), carotene (n = 3, citations per paper = 637), ferulic acid (n = 2, citations per paper = 629) and caffeic acid (n = 3, citations per paper = 604), isoflavonoid (n = 4, citations per paper = 594), catechin (n = 3, citations per paper = 584), cinnamic acid (n = 2, citations per paper = 580), procyanidin (n = 2, citations per paper = 557), lignin (n = 6, citations per paper = 545), and ellagic acid (n = 4, citations per paper = 543).

[Figures 2 and 3]

Meanwhile, the most frequently mentioned berries were strawberry (n = 18, citations per paper = 423), blueberry (n = 16, citations per paper = 456), cranberry (n = 13, citations per paper = 395), raspberry (n = 12, citations per paper = 485), blackberry (n = 12, citations per paper = 463), bilberry (n = 10, citations per paper = 441), and grape berry (n = 10, citations per paper = 351). However, it should be noted that the studies usually investigated multiple berries species, as demonstrated by these studies [28-30], instead of focusing on a single one.

3.5. Study limitations

One potential limitation was that the list is compiled by extracting data from Scopus database only, meaning that manuscripts not listed in Scopus were not included in the current report. Scopus in particular was chosen due to its broader coverage of biomedical literature relative to Web of Science, another well-known database that keeps track of citation data [31]. On the other hand, Google Scholar, for example, counts citations from non-academic sources such as websites, and hence was not selected by us for the current analysis.

4. Conclusions

A bibliometric analysis was performed to identify the 100 most cited berry-related papers. The *Journal of Agricultural and Food Chemistry* was the preferred choice of publication outlet. The total citation count and adjusted citation count did not appear to have a significant correlation with the number of authors or the journal impact factor. Antioxidant and anti-cancer benefits seemed to be the major topics. Berries species that were mentioned in at least 10% of the 100 papers were strawberry, blueberry, cranberry, raspberry, blackberry, bilberry, and grape berry.

Conflict of interest: The authors have no conflict of interest to report.

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Figure Captions

Figure 1. Distribution of the 100 most cited berry-related papers across the publication years. Year 2007 was the most influential year when 16 out of the 100 most cited berry-related papers were published.

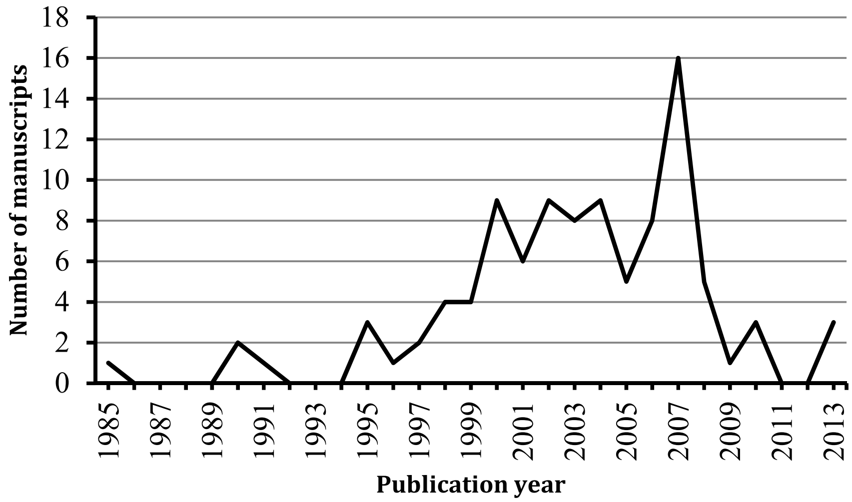

Figure 2. Term map of words from the titles and abstracts of the 100 most cited berry-related papers. There were 731 words or phrases that appeared in at least two papers and hence included in the visualization. Each bubble represents a term or phrase. The bubble size indicates its number of appearance. The bubble color indicates the averaged citation count received by papers containing the term or phrase. Two bubbles are closer to each other if the two terms co-appeared in more papers. It seemed that antioxidant capacity and angiogenesis effect were the two major aspects under investigation that may lead to potential health benefits against cancer and chronic diseases.

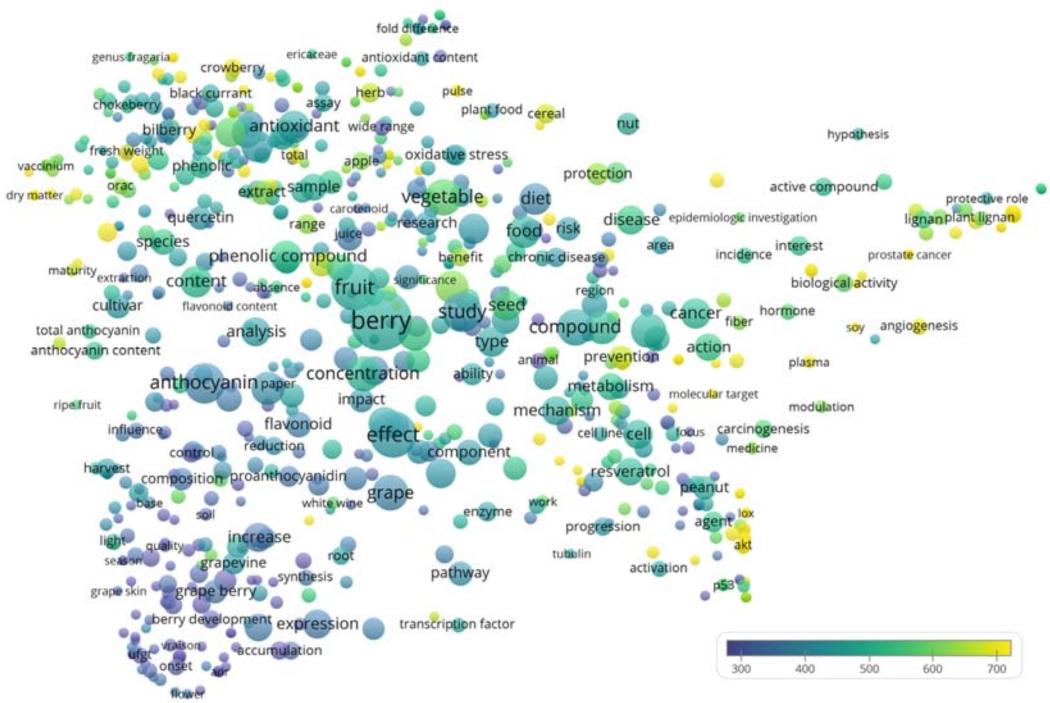

Figure 3. Notable representative molecules mentioned by berry-related papers. The respective search name and citation per manuscript are in parenthesis.

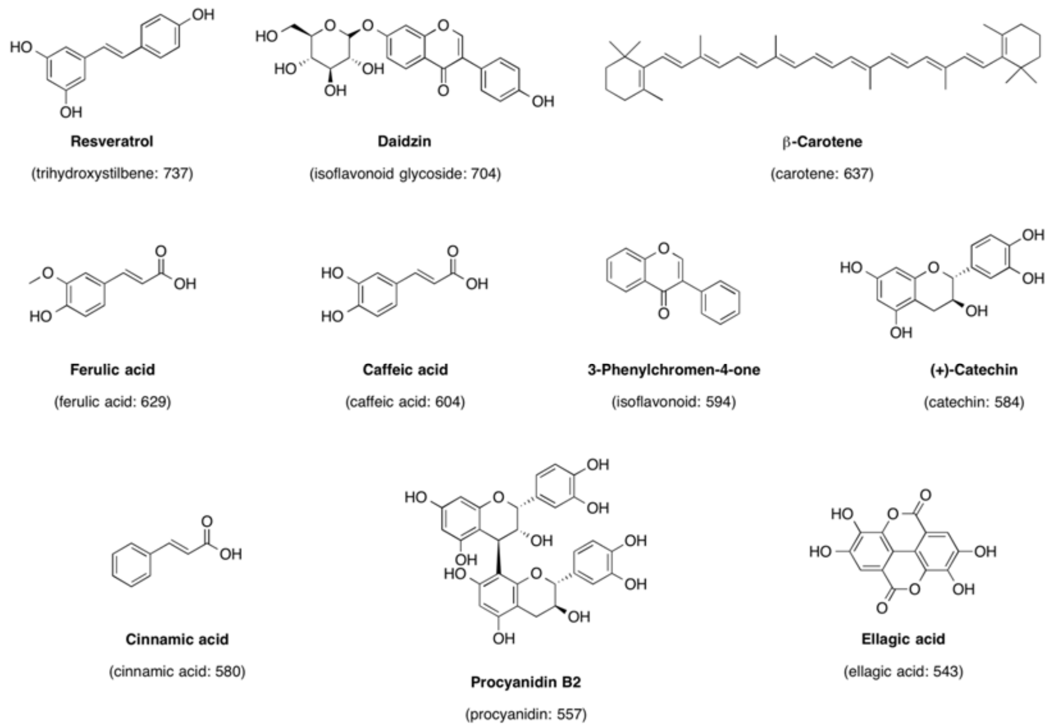

Table 1. The list of 100 most cited berry-related papers.

Rank	Reference	Impact factor (IF)	Total citation count	Adjusted citation count
1	Kähkönen MP, Hopia AI, Vuorela HJ, Rauha J, Pihlaja K, Kujala TS, Heinonen M. Antioxidant activity of plant extracts containing phenolic compounds. J Agric Food Chem 1999;47(10):3954-62.	3.412	2190	115.3
2	Aggarwal BB, Shishodia S. Molecular targets of dietary agents for prevention and therapy of cancer. Biochem Pharmacol 2006;71(10):1397-421.	4.235	1196	99.7
3	Frémont L. Minireview: Biological effects of resveratrol. Life Sci 2000;66(8):663-73.	3.234	1119	62.2
4	Adlercreutz H, Mazur W. Phyto-oestrogens and western diseases. Ann Med 1997;29(2):95-120.	3.007	1029	49.0
5	Aggarwal BB, Bhardwaj A, Aggarwal RS, Seeram NP, Shishodia S, Takada Y. Role of resveratrol in prevention and therapy of cancer: Preclinical and clinical studies. Anticancer Res 2004;24(5 A):2783-840.	1.865	985	70.4
6	Clifford MN. Chlorogenic acids and other cinnamates - nature, occurrence and dietary burden. J Sci Food Agric 1999;79(3):362-72.	2.379	896	47.2
7	Leuning R. A critical appraisal of a combined stomatal-photosynthesis model for C_3 plants. Plant Cell Environ 1995;18(4):339-55.	5.415	896	39.0
8	Pellegrini N, Serafini M, Colombi B, Del Rio D, Salvatore S, Bianchi M, Brighenti F. Total antioxidant capacity of plant foods, beverages and oils consumed in Italy assessed by three different in vitro assays. J Nutr 2003;133(9):2812-9.	4.398	873	58.2

9	Prior RL, Cao G, Martin A, Sofic E, McEwen J, O'Brien C, Lischner N, Ehlenfeldt M, Kalt W, Krewer G, Mainland CM. Antioxidant capacity as influenced by total phenolic and anthocyanin content, maturity, and variety of *Vaccinium* species. J Agric Food Chem 1998;46(7):2686-93.	3.412	867	43.4
10	Lindström J, Tuomilehto J. The diabetes risk score: A practical tool to predict type 2 diabetes risk. Diabetes Care 2003;26(3):725-31.	13.397	847	56.5
11	Wang SY, Lin H-. Antioxidant activity in fruits and leaves of blackberry, raspberry, and strawberry varies with cultivar and developmental stage. J Agric Food Chem 2000;48(2):140-6.	3.412	812	45.1
12	Fukumoto LR, Mazza G. Assessing antioxidant and prooxidant activities of phenolic compounds. J Agric Food Chem 2000;48(8):3597-604.	3.412	798	44.3
13	Del Rio D, Rodriguez-Mateos A, Spencer JPE, Tognolini M, Borges G, Crozier A. Dietary (poly)phenolics in human health: Structures, bioavailability, and evidence of protective effects against chronic diseases. Antioxid Redox Signal 2013;18(14):1818-92.	6.530	777	155.4
14	Halvorsen BL, Holte K, Myhrstad MCW, Barikmo I, Hvattum E, Remberg SF, Wold A-, Haffner K, Baugerød H, Andersen LF, Moskaug O, Jacobs Jr. DR, Blomhoff R. A systematic screening of total antioxidants in dietary plants. J Nutr 2002;132(3):461-71.	4.398	740	46.3
15	Kähkönen MP, Hopia AI, Heinonen M. Berry phenolics and their antioxidant activity. J Agric Food Chem 2001;49(8):4076-82.	3.412	678	39.9
16	Sivapalasingam S, Friedman CR, Cohen L, Tauxe RV. Fresh produce: A growing cause of outbreaks of foodborne illness in the United States, 1973 through 1997. J Food Protection 2004;67(10):2342-53.	1.510	663	47.4
17	Adlercreutz H. Western diet and western diseases: Some hormonal and biochemical mechanisms and associations. Scand J Clin Lab Invest 1990;50(s201):3-23.	1.498	627	22.4

18	Moyer RA, Hummer KE, Finn CE, Frei B, Wrolstad RE. Anthocyanins, phenolics, and antioxidant capacity in diverse small fruits: *Vaccinium*, *Rubus*, and *Ribes*. J Agric Food Chem 2002;50(3):519-25.	3.412	625	39.1
19	Rauha J-, Remes S, Heinonen M, Hopia A, Kähkönen M, Kujala T, Pihlaja K, Vuorela H, Vuorela P. Antimicrobial effects of Finnish plant extracts containing flavonoids and other phenolic compounds. Int J Food Microbiol 2000;56(1):3-12.	3.451	619	34.4
20	Kumar S, Pandey AK. Chemistry and biological activities of flavonoids: An overview. Sci World J 2013;2013:162750.	No IF	618	123.6
21	Herman C, Adlercreutz T, Goldin BR, Gorbach SL, Hockerstedt KAV, Watanabe S, Hamalainen EK, Markkanen MH, Makela TH, Wahala KT, Hase TA, Fotsis T. Soybean phytoestrogen intake and cancer risk. J Nutr 1995;125(3 SUPPL.):757S-70S.	4.398	578	25.1
22	Spayd SE, Tarara JM, Mee DL, Ferguson JC. Separation of sunlight and temperature effects on the composition of *Vitis vinifera* cv. merlot berries. Am J Enol Vitic 2002;53(3):171-82.	1.765	535	33.4
23	Reid KE, Olsson N, Schlosser J, Peng F, Lund ST. An optimized grapevine RNA isolation procedure and statistical determination of reference genes for real-time RT-PCR during berry development. BMC Plant Biol 2006;6:27.	3.930	530	44.2
24	Puupponen-Pimiä R, Nohynek L, Meier C. Antimicrobial properties of phenolic compounds from berries. J Appl Microbiol 2001;90(4):494-507.	2.160	520	30.6
25	Adlercreutz H. Phytoestrogens: Epidemiology and a possible role in cancer protection. Environ Health Perspect 1995;103(SUPPL. 7):103-12.	8.309	504	21.9
26	Zafra-Stone S, Yasmin T, Bagchi M, Chatterjee A, Vinson JA, Bagchi D. Berry anthocyanins as novel antioxidants in human health and disease prevention. Mol Nutr Food Res 2007;51(6):675-83.	5.151	497	45.2
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