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EXPLORING THE CHARACTERISTICS AND EFFECTS OF DATE PALM WASTE ON SOME PROPERTIES OF CONCRETE: A REVIEW

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ABSTRACT

The growing concern about environmental pollution and the depletion of resources has led to a focus on the use of more sustainable materials. In light of this, the recycling and use of agricultural wastes is highly advanced and sought-after in the concrete technology field. Yearly, an enormous quantity of date palm waste (DPW) is produced, putting stress on the ecosystem and necessitating an urgent disposing method. For this reason, many researchers are looking into the feasibility of incorporating DPW for cement composites in an effort to improve the performance and sustainability of concrete. The use of DPW in the design of concrete and mortar mixes has a significant effect on both the fresh and hardened properties of the resulting composites. This paper reviews the basic information on the types and characteristics of DPW used in previous studies. In addition, the potential inclusion of DPW and its effect on cement-concrete performance are reviewed. This study further highlights the areas that need additional investigation for adopting these waste materials. This will advance academic research and benefit the sustainability of the construction industry.

KEYWORDS

Date Palm Waste, Natural Fibers, Ash, Concrete, Sustainability.

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1. INTRODUCTION

The date palm is one of the earliest domesticated fruit trees in the Old World, and it is believed that the original homeland of the date palm was in Mesopotamia (land between the great rivers Tigris and Euphrates) before 6000 years ago. The date palm tree can withstand harmful conditions like hot weather, an arid or semiarid environment, and saline soil. Therefore, the worldwide number of date palm trees is estimated to reach 150 million, covering an area of about 11.8 million hectares, mainly in the Middle East and north Africa (Jain and Johnson, 2015). The numbers of date palm trees in some Arabic countries are shown in Fig. 1. (Jain and Johnson, 2015) and (Bamaga, 2022).

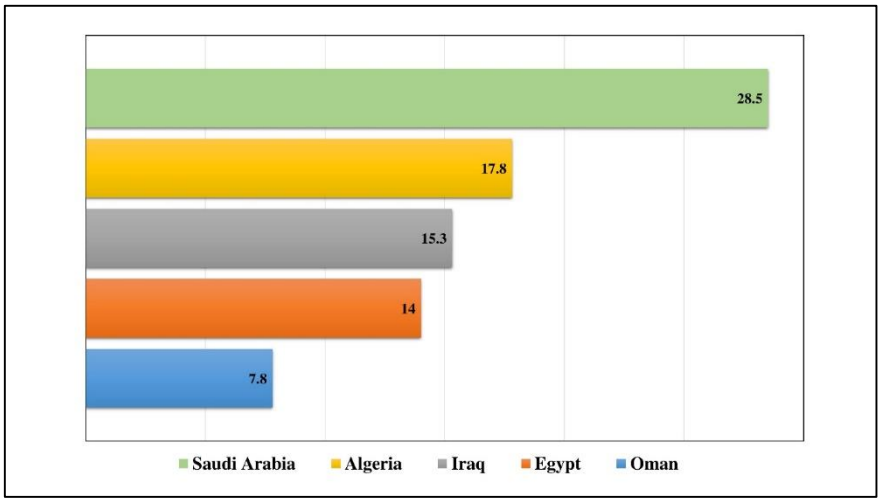


Fig. 1. Number of date palm trees in some Arabic countries by millions.

The global output of date palm fruits produced increased by 12.11% between 2010 and 2018, as reported by the United Nations Food and Agriculture Organization (FAO, 2018), whereas Egypt took the first level as the largest date producer with 1,562,170 mt, followed by Saudi Arabia with 1,302,850 mt, then Iran with 1,016,000 mt, and about 614,584 mt from Iraq (Taban et al., 2021). On the whole, the seasonal trimming and pruning process for each palm tree will produce about 25–35 kg of agriculture waste (Abbas, 2021) and (Althoey et al., 2022). Consequently, millions of tonnes of date palm waste have been generated every year, and most of this waste is disposed of in landfills or burned in open areas, causing serious environmental pollution. On the other hand, the continuous development of infrastructure and the construction industry worldwide make concrete a major building material substance. It is anticipated that the annual demand for concrete would rise to as much as 18 billion tons by the year 2050. Therefore, excessive usage of concrete has been accused of having a negative environmental impact related to the depletion of natural resources and greenhouse gas emissions (Ahmed, 2021). The employment of agricultural waste products, such as rice husk ash, biomass ash,

wood ash, palm oil fuel ash, etc., as substitutes for cement or aggregates is a contemporary approach to mitigating the adverse effects of concrete. In this sense, additional attempts have been put forward to use the abundant waste of date palm as a renewable resource in the production of concrete. As a result, this will provide the appropriate conditions for the elimination of environmental pollution, economic benefit, the preservation of natural resources, and a positive influence on some concrete properties.

This study aims to provide an overview of the literature on date palm waste processing techniques and properties, as well as their prospective uses in concrete. In addition, the impact of using various date palm waste types in concrete has been evaluated and debated. This review will highlight the gaps that need further research to support the fundamental sustainability of the concrete industry.

2. DATE PALM TREE WASTE

The date palm tree produces a variety of waste products during its life cycle. The structural form of the main parts of the date palm tree consists of fibrous composites like wood fiber in the trunk, mesh fiber (around the trunk), frond bunches, rachis, and petioles (Al-Kutti et al., 2021). Date seeds are another form of by-product that may be obtained from date palms. Date seeds account for around 10% of the fruit's total weight (Awad et al., 2021). Thus, natural fibers and ashes from wood or date seeds are the two primary date palm wastes employed in the most previous studies of concrete technology.

2.1. Natural fibers

The utilization of natural fibers as reinforcement in cement-based materials is a distinctive approach for streamlining the disposal of agricultural waste. The researchers and scientists were motivated to explore the use of date palm fibers as a substitute for traditional fibers in the production of concrete composites due to local availability, low cost, lightweight, and durability (Bamaga, 2022). The features of the fibers extracted from date palms are critical criteria that have direct influence on the qualities of cement-based products. Table 1 displays the shapes and properties of date palm fibers utilized in previous researches.

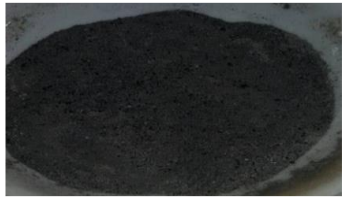
2.2. Date palm ash (DPA)

The incorporation of date palm waste as supplementary cementitious materials (SCMs) is an initiative that has been implemented to mitigate agro by-products and promote the development of sustainable concrete. Prior studies focused on the substitution of ordinary Portland cement (OPC) with date palm ash derived from various sources in the date palm tree, such as wood,

fibers, leaves, or seeds. After the seasonal trimming of date palms, a usual procedure for making date palm ash involves burning these residues at a specific temperature after drying, pulverizing, and sieving. Based on some earlier studies, Table 2 provides a brief overview of the processing technique as well as the appropriate burning temperature to generate various kinds of date palm ash.

Table 2. Production and Characteristics of Date palm ash

Reference	Source of waste	Main process steps	Burning temperature /time	Final product
(Nasir et al., 2021) , (Nasir, and Al-Kutti, 2018), (Al-Kutti, et al., 2018)	Fronds and Petioles 	- Drying the raw materials under sun for 1 day. - Grinding the wastes by hammer mill - Passing through 8 mm sieve - compressing and molding - Burning using raw waste materials as fuel.	700 °C for 6 hr	
(Nassef et al., 2021)	Palm leaves	- Drying in the air - Burning using an oven in the presence of air.	Burn for 1 hr.	

(MA**logla and Almusayrie, 2022**)	**(Smith et al., 2020)** **21-2** **[23] / [24]**	**(Alsalami et al., 2018)**
Date palm leaf (branches) 	Date palm seeds	 Date palm kernel shell
 	- Burn the seed in kiln at two stages, Firstly: at 590 °C for 8 hr, then allowed to cool for two days. Secondly: re-burn at 630 °C for 3 hr followed with another 3 days for cooling. Sieved the obtained ash using 75-micron sieve.	- Washing with water. - Drying under sun for a number of days. - Crushing by special kernel mill. - Burning crushed powder at furnace
- Burn the branches in open air for about 20 minutes as in figure. -Extinguish the fire with water. -Drying the remaining ash using basic stove as shown. -Finally, grinded the dry ash, then sieved by sieve No.40 (420 µm).	590 °C for 8 hr. Then 630 C for 3 hr	850 °C at 2 hr.
		

Date palm ash was analyzed for its chemical composition by several researchers using an X-ray fluorescence spectrometer. The results indicated the presence of significant quantities of silica and calcium oxide, along with other oxides, as presented in Table 3.

Table 3. Chemical composition of date palm waste ash.

References	Chemical oxides (%)									
	SiO_2	Fe_2O_3	Al_2O_3	CaO	Cl	MgO	K_2O	Na_2O	SO_3	LOI
(Nasir, and Al-Kutti, 2018), and (Nasir et al., 2021)	42.2	3.2	1.1	19.2	7.0	14.1	5.7	0.9	3.6	1.1
(Al-Kutti, et al., 2018), and (Al-Kutti, et al., 2019)	35.93	0.78	0.65	13.04	/	6.36	7.4	3.6	/	8.41

3. EFFECT OF DATE PALM WASTES ON THE PROPERTIES OF CONCRETE AND MORTAR

3.1. Workability

Workability is one of the most essential characteristics of fresh concrete and has a direct effect on the mechanical and long-lasting properties of hardened concrete. Several researchers looked at how using date palm waste might affect the workability of the concrete.

In their investigation, (Aminova, and Sikora, 2022) found that the concrete mixture's inclusion of date palm fibers had low workability. The slump values exhibited a significant decrease, from 9 cm of reference mix to 4 cm and 0 cm for mixes that incorporated 1% and 2% date palm fibers by cement mass, respectively. In addition, (Bamaga, 2022) discovered that the level of workability steadily decreased with increasing doses of date palm mesh fibers at 1%, 2%, and 3%. In accordance with the results of the flow table test, the diameter of the mortar decreased by 11.37, 21.07, and 24.25%, respectively.

Similarly, the researcher (Bamaga, 2022) discovered that the workability of mortar is negatively impacted by the length of date palm fibers. The study has revealed that the incorporation of fibers with lengths of 10mm, 20mm, and 50mm in mortar has resulted in a reduction of workability by 4.2%, 5.5%, and 7.6%, respectively, in comparison to the reference mix. The decrease in workability may be attributed to the porous characteristics and high water absorption capacity of fibers derived from date palms. On the other hand, various research have

examined at how date palm ash affects the workability of cement materials. Nasir and Al-Kutti, (2018) elucidated a flow test reduction for mortar through the utilization of date palm ash (DPA) as a substitute for cement. The flow diameter of mixtures containing 10%, 20%, and 30% DPA were observed to be lower than that of the reference mixture (measuring 180 mm) at rates of 5.5%, 12.7%, and 16.1%, respectively. The study conducted by Alsalami et al., (2018) revealed that the incorporation of palm kernel ash as a substitute for cement in high performance concrete resulted in a reduction in workability. Specifically, the slump value decreased from 180 mm to 150, 145, and 140 mm for dosages of 10%, 15%, and 20%, respectively. According to the findings of Smith et al., (2021) the slump outcomes exhibited a reduction in values with an increase in the proportion of date palm seed ash utilized as a substitute for cement. The dosages of date seed ash considered in the study were 2.5%, 5%, 7.5%, 10%, 15%, and 20%. Here, the slump value decreased from an initial value of 60 mm to 58 mm, 56 mm, 54 mm, 50 mm, 36 mm, and 24 mm, respectively.

Based on the findings of previous research, which are shown in Fig. 2, it is widely agreed upon that concrete or mortar that contains waste date palm as fibers or ash might demonstrate reduced workability in comparison to materials that do not include waste.

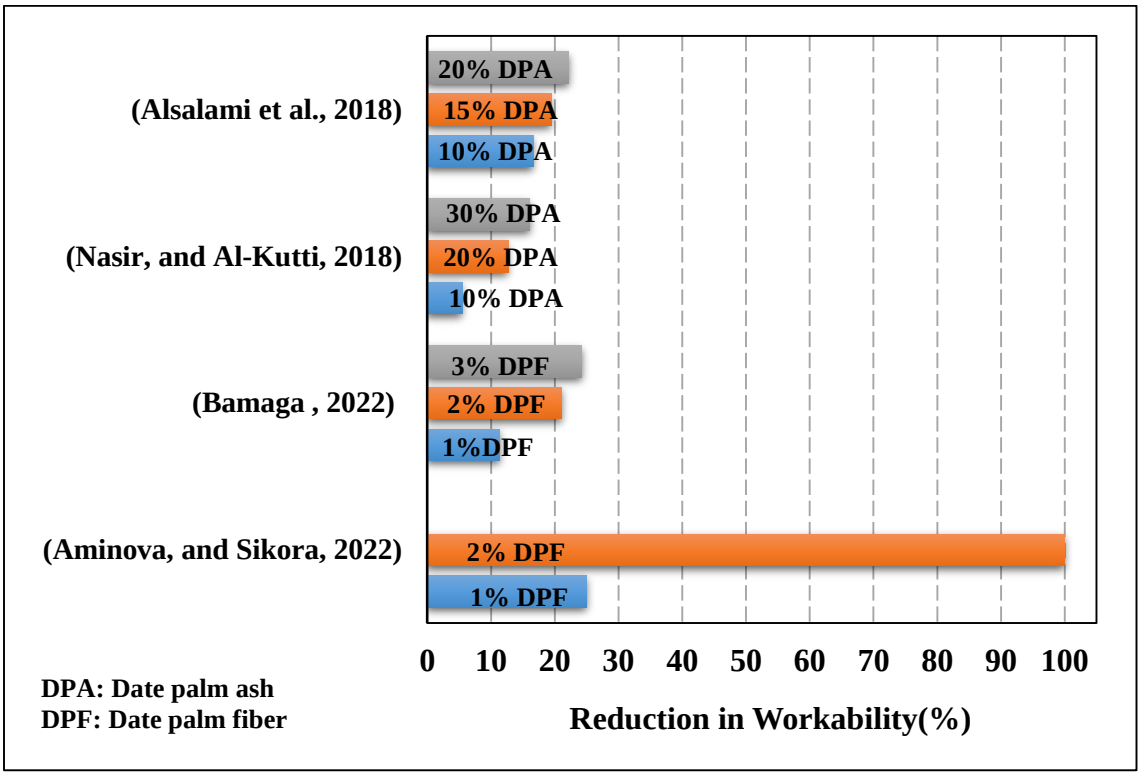


Fig. 2. Effect of date palm waste on the concrete workability.

3.2. Density

Alsalami et al., (2018) discovered that the density of high performance concrete mix decreased from 2443 kg/m3 to 2235, 2230, and 2225 kg/m^3 when the cement was substituted with 10%, 15%, and 20% palm kernel ash, respectively. Additionally, the substitution of sand with 10%, 15%, and 20% crushed date palm kernel shell brought the density down to 2220 kg/m^3 for the 20% dose. This was achieved by increasing the percentage of crushed date palm kernel shell used. Althoey and Hakeem, (2022) reported that the replacement of steel fibers with date palm fibers has decreased the fresh and hardened density of ultra-high performance concrete.

In a similar vein, increasing the date palm fibers content from 0.6% to 1.0% lowered the density of high strength concrete from 2511 kg/m^3 to 2509 and 2496 kg/m^3, respectively (Althoey et al., 2022). Mouthanna, (2022) determined that an increase in the proportion of date palm fibre in concrete mixtures resulted in a decrease in the density of the resulting compounds. According to Bamaga's research, it was observed that the apparent density of cement mortar decreased with the increase in the length of date palm fibers. Incorporating date palm leave fibers with varying lengths of 10, 20, and 50 mm at a proportion of 3% resulted in a reduction of the density of the control mixture by approximately 0.9%, 1.3%, and 1.9%, respectively (Bamaga, 2022). The reduction in the weight of concrete is primarily attributed to the porous structure and lower density of date palm fibers, which result in the formation of voids within the concrete matrix.

3.3. Compressive strength

Extensive studies of the impact of discarded date palm on the mechanical properties of cement based composites have been conducted during the past several decades. Compressive strength is a key indicator of other mechanical and durability characteristics of concrete, making it one of the most significant aspects of the material. The compressive strength of mortar was investigated by Nasir and Al-Kutti, (2018) through the utilization of date palm ash as a cement replacement at varying percentages of 10%, 20%, and 30%. At 28 days, the highest strength of 56.8 MPa was observed for the 10% DPA mixture, surpassing the control mix, as well as the 20% and 30% DPA mixtures by 2.4%, 23.7%, and 28.5%, respectively. The study conducted by Nassef et al., (2021) provides conformation that the substitution of cement with palm leaves ash results in an enhancement of the compressive strength of concrete. The incorporation of palm ash at a proportion of 5% resulted in a significant enhancement of the compressive strength, exhibiting an increase of 36% and 25% at 7 and 28 days, respectively. Upon administering a 10% dosage of palm ash, the compressive strength exhibited a 6% and 13%

increase after 7 and 28 days, respectively. This indicates that the use of palm ash has a positive impact on the strength of the material.

In the same context, Al-Kutti et al. (2019) conducted a study wherein they replaced cement with date palm ash (PA) derived from the incineration of deceased fronds of date palm trees. The substitution was carried out at varying proportions of 10%, 20%, and 30%. The findings indicate that the mortar specimens that contained 10% PA exhibited the most notable initial strength development, followed by those with 30% PA, 100% OPC, and 20% PA specimens in descending order of effectiveness. The compressive strength of specimens containing 10% PA after 28 days was measured to be 56.8 MPa. This value was found to be higher than that of specimens containing OPC, 20% PA, and 30% PA by approximately 2.5%, 28.5%, and 24%, respectively. Additionally, the potential of incorporating palm tree leaves ash (PTA) as a cement replacement in concrete was assessed by Alogla and Almusayrie, (2022) through an evaluation of the compressive strength of PTA concrete. The concrete was supplemented with PTA in three different concentrations (5%, 10%, and 15%) as a replacement for cement based on weight. The authors found that the compressive strength of the reference mix after 28 days exhibited an increase from 40.3 MPa to 44.9 MPa when the mix included 5% PTA. Upon substitution of the cement with 10% and 15% PTA, a reduction in compressive strength of 46.6% and 43.9% was observed, respectively.

On the other hand, a number of researchers have observed the impact of fibers derived from date palms on the compressive strength of concrete. The study conducted by Alatshan et al., (2017) determined that incorporating date palm surface fibers with lengths of 50 mm at concentrations of 0.5%, 1%, and 1.5% resulted in a significant enhancement of compressive strength. The optimal attained strength was about 30.6 MPa at a dosage of 0.5%. The observed outcome of increasing date palm fibers to 2% and 2.5% resulted in a reduction in strength up to 26.6 and 26.1 MPa respectively.

Mouthanna, (2022) used date palm fronds fibers at 0.25%, 0.5%, 0.75%, and 1% by volume of concrete. The main finding is decreasing of compressive strength with increase of fiber content. The strength of control mix (30 MPa) has been dropped to reach approximately 28, 25.5, 22.5 and 20.5 MPa for the above fiber dosages respectively. The investigation carried out by Bamaga (2022) employed date palm mesh fibers that were 50 mm in length. These fibers were incorporated into the mortar mixture at varying weight percentages of 1%, 2%, and 3%. The findings indicate an increase in the proportion of natural fibers leads to a reduction in compressive strength. After 28 days, the compressive strength of the control mixture was

decreased from 20.63 MPa to 14.65, 10.90, and 8.74 MPa, respectively. Not much differs; the study conducted by Aminova and Sikora, (2022) revealed that the incorporation of natural fibers derived from crown date palm at concentrations of 1% and 2% resulted in a decrease in the compressive strength of concrete from 36.6 MPa to 33.1 and 32.0 MPa, respectively.

3.4. Flexural strength

The flexural strength of concrete has an effect on its deflection, shear strength, and ductility properties. The flexural strength of concrete is an essential attribute that must be considered during the design process. Most studies found that the inclusion of date palm fibers in cement-based composites enhanced flexural behavior.

According to Althoey et al., (2022) the incorporation of date palm fibers resulted in a notable enhancement of the flexural strength of the high-strength concrete. The flexural strength of specimens with date palm fibers at levels of 0.2%, 0.6%, and 1% exhibited increases of 60%, 77%, and 85%, respectively, when compared to the reference mixture. In addition, Alatshan et al., (2017) discovered that using DPF increased the flexural strength of concrete. When compared to the general trend of findings, the greatest improvement was shown at a dose of 0.5% for 50 mm length fibers and a best improvement at a dosage of 1% for 60 mm length fibers. The most effective dose for fibers of 70 mm length was 0.5%.

According to the findings of Aminova and Sikora (2022), the incorporation of 1% DPF resulted in a rise in the flexural strength of concrete from 4.15 MPa to 4.20 MPa. However, the flexural strength decreased to 3.95 MPa when the DPF content was increased to 2%. However, the flexural strength of concrete might be compromised when cement is substituted with date palm ash. Flexural strength was shown to diminish when palm kernel ash (PKA) replacement percentages were increased, as described by Alsalami et al., (2018). Weak adhesion between data palm kernels and cement paste may be reason for this behavior.

3.5. Miscellaneous properties

The effects of using date palm waste on different properties of concrete or mortar are summarized in Table 4. The table below summarizes the available literature on the subject of concrete's water absorption and some properties.

Table 4. Effect of date palm waste on some properties of concrete

References	Type of waste	Using Ratio (%)	Tests	Main findings
Althoey et al., (2022)	Date palm fibers	0.2 , 0.6 and 1	- Water absorption -Water permeability - Ductility - Ultrasonic pulse velocity	* The water absorption increased with the increase of DPF * The water permeability increased by 14%, 96% and 143% respectively. * The ductility index of the date palm fiber-reinforced concrete was improved * The UPV of the high-strength concrete showed a decreasing pattern as the volume fractions of date palm fiber increased.
(Bamaga, 2022)	Date Palm Leave Fibers	1 and 3	Water absorption	The mortar specimens of date palm fibers have higher water absorption as compared to control mix.
Al-Kutti et al., (2019)	Date palm ash	10, 20, and 30%	- water absorption - Rapid chloride permeability	- The specimens of 10% PA lowest water absorption rate in both the beginning and final phases, followed by 20% PA, OPC, and 30% PA. - The inclusion of 10% DPA showed highest resistance to the permeability of chloride ions followed by the samples of 100% OPC, 20% PA and 30% PA, respectively.
(Smith et al., 2020), (Smith et al., 2021)	Date palm seed ash	2.5, 5, 7.5, 10, 15, and 20	water absorption	The use of DPSA in concrete reduced the water absorption capacity of concrete as more cement was replaced with DPSA.

4. CONCLUSIONS

This review paper conducts an analysis of some of the previous studies in related to the potential use of date palm waste in different forms in the concrete. It examines the impact of incorporating these waste materials as either natural fibers or cementitious replacements on the properties of both fresh and hardened concrete. The most important conclusions from this review's findings are as follows:

- Using date palm waste as an ingredient in concrete production satisfies the need for sustainability associated with decomposition and recycling of this type of agricultural consumer waste.

- The workability of concrete has decreased with the inclusion of date palm waste. The most significant reduction appears for mixtures containing date palm fiber compared with those containing date palm ash.

- The fresh density of concrete, as well as its hardened density, was found to be reduced as a consequence of the use of waste from date palms in the form of fiber or ash.

- Many studies have shown a positive correlation between the use of date palm ash as a cement replacement and the enhancement of compressive strength in concrete. In contrast, a reduction in strength may be seen in concrete compositions including date palm fibers, particularly when used in higher proportions.

- The flexural strengths of concrete containing waste date palm fibers are greater than those of ordinary concrete. However, some results show that the inclusion of date palm ash as a cement replacement will minimize the flexural strength due to weak bonding in cement paste composites.

- There is a positive effect on reducing the water absorption of concrete by using date palm waste ash; consequently, the durability properties will be enhanced. Meanwhile, the inclusion of date palm fiber will increase the permeability of the concrete due to the presence of more voids and pores in the concrete matrix.

- Recycling waste of date palms into concrete is a clean solution to producing more eco-friendly building materials. The advantages of including these wastes are not limited to the reduction of greenhouse gas emissions, waste management, and cost effectiveness, but also to improve some properties of concrete and durability performance

- Further researches are required to complete the evaluation of waste date palm on other properties of concrete such as thermal insulation, fire resistance, impact resistance, creep and shrinkage.

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