

5HVH DUFK \$UWLF OH 20,&6 ,QWH

&RPSDULVRQV RI &RRNLQJ DQG HDWLQJ TXDOLWLHV

1QDHPND (PPDQXHO/2NSDOD) RDQ 6KHX TXDQ =DQJ;LDRTXDQ 4L
.H\ /DERUDWRU\ RI 3ODQW 0ROHFXODU 3K\VLRRJ\ ,QVWLWXWH RI %RWDQ\ &KLQHVH \$FDGHP\ RI 6FLHQF
8QLYHUVLW\ RI &KLQHVH \$FDGHP\ RI 6FLHQFHV %HMLQJ &KLQD
*XDQJGRQJ .H\ /DERUDWRU\ RI 3ODQW 0ROHFXODU %UHGHLQJ &ROOHJH RI \$JULFXOWXUH 6RXWK &KLQD
&RUUHVSRLQGLQJ JUDQXOH PRUSKRORJ\ ;LDRTXDQ 4L .H\ /DERUDWRU\ RI 3ODQW 0ROHFXODU 3K\VLRRJ\ ,QVWLWXWH
(PDLO [TL#LEFDV DF FQ
5HFHYHG GDUHFK \$FFHSWHG GDUHFK 03XEOLVKHG GDUHFK
&RSULJKW 2NSDOD 1(HW DO 7KLV LV DQ RSHQ DFFHVV DUWLF OH GLVWULEXWHG XQG HU WKH WHUPV RI
XVH GLVWULEXWLRQ DQG UHSURGFWLRQ LQ DQ\ PHGLXP SURYLGHG WKH RULJLQDO DXWKRU DQG VRXU

\$EVWUDFW
7KH FRRNLQJ DQG HDWLQJ TXDOLWLHV RI ULFH DUH VRPH RI WKH SUREOHPV I
DURXQG WKH ZRUOG ,Q WKLV VWXG\ ZH LQYHVWLJDWHG WKH FRRNLQJ DQG HDWL
%RWK DUH ULFH FXOWLYDUV ZLWK GLIIHUHQW SKHQRW\SLF WUDLWV
7KH UHVXOWV VKRZ WKDW %DVPDWL LQFUHDVHG E\ DQ DYHUDJH RI DIW
LQFUHDVHG E\ DQ DYHUDJH RI DIWHU FRRNLQJ %DVPDWL KDG D SDVWLQJ
;LDQ KDG D SDVWLQJ WHPSHUDWXUH RI f& +RZHYHU +XD -LQJ ;LDQ KDG
%DVPDWL KDG D ILQDO YLFRVLW\ RI F3 7KH DP\ORVH FRQWHQWV RI WKH
-LQJ ;LDQ KDG DQ DP\ORVH FRQWHQW RI ZKLOH WKDW RI %DVPDWL ZDV
VWUFXODU JUDQXOH PRUSKRORJ\ RI WKH WZR FXOWLYDUV ZHUH UHPDUNDEO\ GLIIHU

.H\ZRUOG &RRNLQJ TXDOLWLHV (DWLQJ TXDOLWLHV) TXDOLWLHV TXDOLWLHV TXDOLWLHV
;LDQ HDWLQJ TXDOLWLHV DQG QXWULWLRQDO TXDOLWLHV
&RRNHG ULFH HORQJDWLRQ ZDWHU DEV
\$EEUHYLDWLRQ %DVPDWL F3 &HQWL SRVLWQJ WHPSHUDWXUH DUH VRPH RULJLQ
;LDQ UHSUHVHQW WKH FRRNLQJ DQG HDWLQJ
VWXG\ ZDV L QVWLWXWH RI 6FLHQFHV
,QWURGXFWRQ EHWZHHQ +XD -LQJ ;LDQ DQG %DVPDWL
5LFH JUDLQ TXDOLWLHV RI WKH OHDGLQJ JUDLQ TXDOLWLHV DQG DP\ORVH FRQW
DQG LV D VWDSOH IRRG IRU RYHU KDQJUDQXOH PRUSKRORJ\ SDVWLQJ WHPSHUDWX
FRPPHUFDO ULFH FXOWLYDUV VSRIHULW KHU
DQG WKHVH VXEVSRIHULW IRU WKH WZR
DQG SK\VLRRJLFDQ WUDLWV > @ ,Q FRQWULHY ZLWK KLJK KXPDO SRSXODWLRQ
OLNH &KLQD DQG ,QLD ULFH LV FRQVPHG GDLO LQ D YDULHW\ RI ZD\ 5LFH
LV WKH PRVW ZLGHO\ FXOWLYDWHG FURS LQ &KLQD 5LFH SURGXFWLRQ LQ ,QLD
KDV LQFUHDVHG UHPDUNDEO\ LQ WKH 5LFH DUWLF OH DQG QRZ UHSUHVHQW
DSSUR[LPDWHO\ RQH WKLUG RI WKH JOREDO ULFH SURGXFWLRQ > @ 5LFH LV DOV
VWDSOH IRRG LQ \$IULFD ZKHUH LW LV FXOWLYDWHG ZLGHO\ ZLWK D VWKLV
LQFUHDVH LQ FRQVXPSWLRQ VDPH FRQGLWLRQHLWV SDUWLHWLHV DUH %
\$V KRXVHKROG LQFRPHV LQFUHDVHV ULFH; FRQVXPSWLRQ DUWLF OH DULF MLH
ZLWK EHWWHU FRRNLQJ DQG HDWLQJ TXDOLWLHV 5LFH JUDLQ TXDOLWLHV UHPDLOV
LPSRUWDQW FRQFHUQ IRU ULFH EUHHGHUV SURGXFWLWY DQG FRQVXPSWLRQ DOV
WKH ZRUOG > @ ,PSURYHPHQW RI JUDLQ TXDOLWLHV LV DQ DLP RU PRVW ULFH
EUHHGHUV EHFDDWH FRPPHUFDO YDOXH RI ULFH > @ ,QFUHDVHG
SURGXFWLWY ULFH LV QHHGHG DOO\ DUWLF OH WKH ZRUOG QRW MXVW
EHFDXVH RI WKH LQHYLWDEOH HSDQVLRQ RI WKH KXPDO SRSXODWLRQ EXW DOV
EHFDXVH RI WKH SURMHFWHG HGHPDUNDEO\ VDWLQJ SURSDUWPHQW HLHV RI +XD -LQJ ;LD

6LQFH SDUW RI WKLW VVXGRVZDW DUFK RYHSDUO HW KHV H[SHULPHQW \$V DOO VROY
PRUSKRORJ\ RQ WKH SDVWLQJ WHPSHZBWXZHRO \$MBVHLWYHGLDQ ULQDQGH WKHU
%DVPDWL ZH GHFLGHG WR DG VWRW HLJKW YDULHWLHV WR VWXG\ WKH
RI VWDFK JUDQXOH PRUSKRORJ\ RQ WKLW SDYSLRSHUPLHV

'HKXVNLQJ PLOOLQJ DQG SXOYHULLP 3DVWLQJ SURSHU\ DQDO\VLV ZDV FDU
7HF0\$67(5 LQVWUXPHQW P/ RI GLVWLOO

:KROH DQG PDWXUH JUDLQV RI WHQ YDURSHUHFVZHVWHGHSXMRUHWGRVLDQGLQQJ J
\$R /LDQJ <RQJ 4L &DL &KDQJ -/*- GH WKXVNFIDRLQVWMLQPHSQMHSUDGQON ZDV SODFH
WKDW JRW EURNHQ GXULQJ WKH SURFHVV ZHUH GLVFDUGHG DV ZHUH LPPDWXUH
JUDLQV :KROH DQG PDWXUH GHKXVNHG FDUHQJULQJLQV FURPHURQPPDPURVFRVSK 6(0
7DL}KRX -LQJ \$R /7-0 PLEOMGFVDFKLRJHPLOOLQJ

ZDV WR UHPRY ULFH EUDQ ZKLFK FRQWLPDQWRIWKV ZDV CRGHZLWK BHLWDFK
WLVVXHV 5LFH JUDLQV ZHUH DOO PLOOHG 5LFH JUDLQV ZHUH FHWGZLWKWKUFDQGHDFDV
VROXWLRQ DQG ZHUH VSXWWHU FRDWHG

OLOOHG ULFH JUDLQV ZHUH SXOYHULLP DQGLZLWKWDFWFK OLWU OLQ 00
H IUHTXHQF\ ZDV VHW DW VHF DQG WKH JUDLQV ZHUH PLOOHG IRU

VHF 1RWH WKDW WKH ULFH JUDLQV ZHUH PLOOHG IRU JUDQXOH PRUSKRORJ\ RI HDFK
WKH VDPSOHV DWVHUXOHGLRQD PDJQL}FRWLRQ DQG H VWDFK JUDQXOHV
FRQVSLFXRQVZLWKFRWLRQ[ERVJQLWFRWLRQ

&RRNHG ULFH HORQJDWLRQ

&RRNHG ULFH HORQJDWLRQ ZDV KUHHSHVXSWWHQHG DV FVKHLRQ
EHWZHHQ WKH OHQJWK RI JUDLQV RPLQDVXUHG EHIRUH DQG

GHWDLQHG FRRNLQJ SURWRFRO EHORZ &RRNHG ULFH HORQJDWLRQ
SUHFLVLRQ LV YHU\ FUXFLDO WKHUHIRUH DOLFURWHN 6FDQDQHU L VFDQQUH

ZDV XVHG WR PDNH DOO RI WKH OHQJWK PHDVXUHPHQWV LQVWUXPHQW > @ DQG %DVP
LQGEADWLYDU > @ 6WXGLHV KDYH VXJJHV

5DZ ULFH DQG FRRNHG ULFH PHDVXUHPHQWV ULFH ZHUH HORQJDWLRQV EOH ULFH YD

)RU HDFK OLQH JUDLQV RI PLOOHG ULFH ZHUH PHDVXUHG DW D WLPH LQ 6FDQO
WUDQVIHUHG WR D 3&5 SODWH FRQW
JUDLQV ZHUH DOORZHG WR 5SDWIRFRQ
ULFH JUDLQV ZDV WKHQ SODFHG LQ D 3
ZHUH LQGLYLGXDOO\ FRRNHG IRU PLC
r&H FRRNHG ULFH JUDLQV ZHUH WKHQ
DQG SODFHG DW 5SDWIRFRQW LQJ IRU PLQ
WHPSHUDWXUH WKH\ ZHUH WUDQVIHUH
ZLWK WKH VFDQQUH \$V ZLWK WKH UDZ
PHDVXUHG VLPXOWDQHRXVO\ WKLW KHO
FRQWHQW WKDW FRXOG KDYH UHVXOWH
PHDVXUHPHQWV SHULPHQWV XVHG JUDLQ
RI WKH WKUHH UHSOLFDFWHV

(ORQJDWLRQ RI FRRNHG ULFH

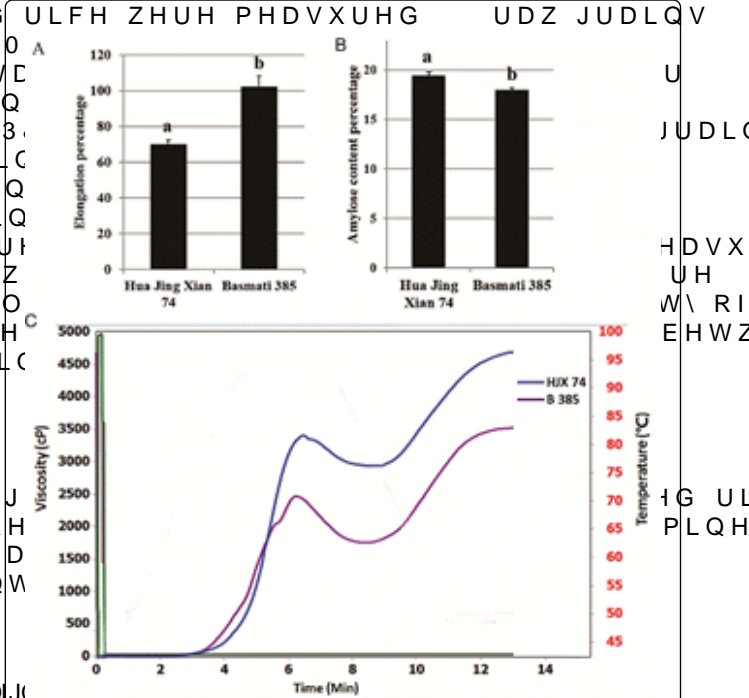
,Q RWKHU WR GHWHUPLQH WKH HORQJ
IRU HDFK FROWLYDU WKH PHDQ YDOXH
EHIRUH DORNLQJ JIROORZLQJ IRUPXOD
GHWHUPLQH WKH HORQJDWLRQ SHUFHQW

Elongation (%E) = $\frac{ACML-BCML}{BCML} \times 100$

:KHUH (LV HORQJDWLRQ SHUFHQW RNDJ
PHDQ OHQJWK DQG %&0/ LV WKH EHIRUH

7RWDO VWDFK DQG DP\ORVH FRQWHQW
DQG %DVPDWL & WKH SURSHUADRLOQ

LVH[SHULPHQW ZDV SHUIRUPHG VWULFDQ\ LQ FRSVORLQV ZLWK WKH
LQVWUXFWLRQV VWLSXODWHG E\ OHJD\PH LQ WKH LQVWUXFWLRQ PDQXDO IRU
WKHLU \$P\ORVH \$P\ORSHFWLQ \$VVD\ NLW KRZHYHU 6RGLXP DJLGH ZDV QRW

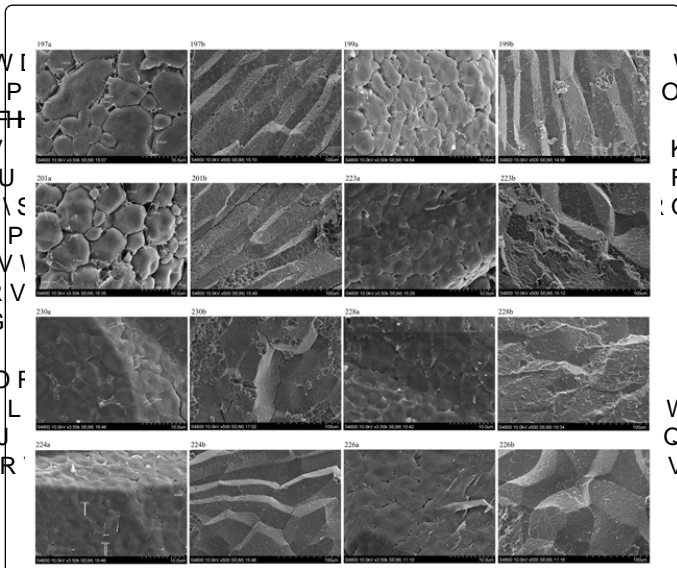


3DJH RI

,Q WKLW VWXG\ WKH OHQJWK RI %DVWUDWFK JUDQXOHV FRPRUSKRORUDJH RI
ZKLOH +XD -LQJ ;LDQ LQFUHDVHG E\ DQ DYHUDJH RI DV DQG K
VKRZQ LQ)LJXUHV \$QVLYH HORQJDWLRQ RI %DVPDWL WKDW DQG K
GHVLUDEOH WUDLW PRUH SURQRXQFHG VWDFK JUDQXOHV FR

\$P\ORVH FRQWHQW

\$P\ORVH FRQWHQW LV DQRWKHU YLW
HDWLQJ TXDOLW\ RI FRRNHG ULFH \$P
UHSRUWHGWR TXDOLW\ RI FRRNHG WLYH
DP\ORVH FRQWHQW FKDUDFWHULVWLFV
SRVWXODWHG WR EH UHVSQVLEOH IRU
WR WUDQVOXFHQW NHUQHOV ZLWK W
> @ 5LFH VWDFK DQVLYH ZLWK DP
ORZ VWDFK DP\ORVH ORZ V
LQWHUPHGLDWH VWDFK DP\ORV
DP\ORVH > @ +XD -LQJ ;LDQ DQG
VWDFK FRQWHQW FDWHJRU\ ZLWK
UHVSHFWLYHO\ 1RWH WKDW WKH DP\O
KLJKHU WKDQ WKDW RI %DVPDWL)L
IRU VRPH ULFH FXOWLYDUV ZLWK ORQJ
6WXGLHV KDYH UHSRUWHG WKDW DP\O
UDQJHG IURP WR > @



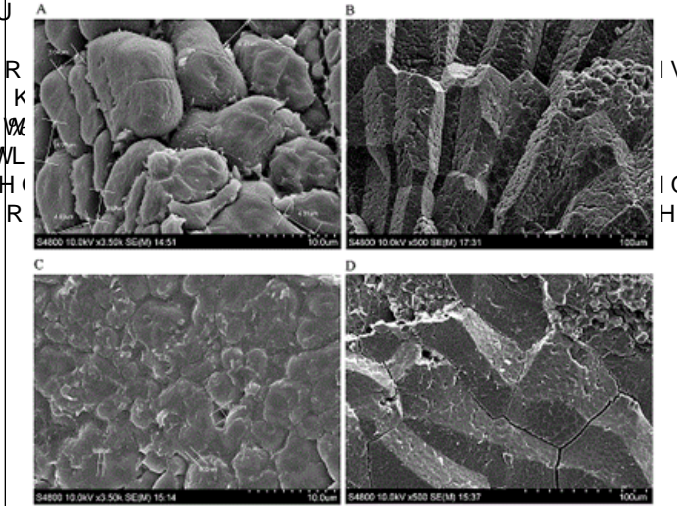
WKH
O\
KDV E
FRPSD
:QWHQV

LV
WHG
QWHQW
VWDFK

3DVWLQJ SURSHUWLHV

3DVWLQJ SURSHUWLHV RI VWDFK
WHPSHUDWXUH DUH LPSRUWDQW LQGLF
GXULQJ SURFHVVQJ 6WDFK LV JHQ
FRQFHUQHG ZLWK WKH HDWLQJ TXDOLW
RI ULFH SDVWLQJ SURSHUWLHV RI VWDFK
VXLWDELOLW\ RI XVH IRU SDUWLFXODU
RWKHU DOOLHG SURGXFW DSSOLFDWLRQ
KDV D QDQVFRVLW\ RI F3 KLJKHU
r& FRPSDUHG WR %DVPDWL WLVZLWK
SDVWLQJ WHPSHUDWXUH RI r& 'XH WR
IURP +XD -LQJ ;LDQ ZLOO OLNHO\ K
FRPSDUHG WR IRRG SURFHVVQJ SURPLW
EDVHG RQ > @ ZKR UHSRUWHG WKDW
FRUHOHWG ZLWK WKH TXDOLW\ RI H
H[FHOHQW LQGLFDWLRQ RI WKH YLFR
PL[LQJ FRRNHU

LDVWUDWFK JUDQXOHV FRPRUSKRORUDJH
WKLW ULFH SDVWLQJ WLVZLWK
ZLWK WKH HDWLQJ TXDOLW\ RI ULFH
SDVWLQJ SURSHUWLHV RI VWDFK
VXLWDELOLW\ RI XVH IRU SDUWLFXODU
RWKHU DOOLHG SURGXFW DSSOLFDWLRQ
KDV D QDQVFRVLW\ RI F3 KLJKHU
r& FRPSDUHG WR %DVPDWL WLVZLWK
SDVWLQJ WHPSHUDWXUH RI r& 'XH WR
IURP +XD -LQJ ;LDQ ZLOO OLNHO\ K
FRPSDUHG WR IRRG SURFHVVQJ SURPLW
EDVHG RQ > @ ZKR UHSRUWHG WKDW
FRUHOHWG ZLWK WKH TXDOLW\ RI H
H[FHOHQW LQGLFDWLRQ RI WKH YLFR
PL[LQJ FRRNHU



IVVHG
IQVV D
HUHG E

7HVW 9DULHW\	3DVWLQJ 7HPS f&

)LJXUHV FDQQQJ HOHFWRQ PLFURJUDSK
PRUSKRORJ\ RI +XD -LQJ ;LDQ DQG %DV
ZLWK JQL}FBWLRQ[% %DVPDWQL}FBZLVWRQ
[& +XD -LQJ PLDQQL}FZLVWRQ' +XD -LQ
;LDQ FZLVWRQ}FBWLRQ

7DEOH SDVWLQJ WHPSHUDWXUH RI HLJKW ULFH FXOWLYDUV

&LWDW2RISDOD 1('XDQ / 6KHQ * =KDQJ * 4L ; &RPSDULVRQV R,IQ&RIFLHQ &XQV6YDVLQ
5HV GRL

3DJH RI

3DWLQGRO - *RQ]DOH] % :DQJ <- }CF&OXQUV\$H \$- 06WDLUFK0)LW]JHUDOG 0\$ &
VWUXFWXUH DQG SK\VLFRFKHPLFDO SURSHUWIDHGVHQVSWDULFCWFRPISRHWUWURFDQQGQVWUX
&HUHDO 6FL &HUHDO &KHP
3XFKRQJNDYDULQ + 9DUDYLQLW 6 %HUJWKDQJHU 1 6LQ&RPSDDWLYH6R&KIG\16 *LOO
RI SLOR VFDOH ULFH VWDUFK SURGXFWLRQW&HUHDO 0 0N0G ILKHH R00RG LFO 08 6UHRSHRWD IHLV D
SURFHVV 6WDUFK 6WDUNH VRXUFHV)RRG &KHP
5DJDDH 6 \$EGHO \$DO (60 3DVWLQJ SURSHUWLHV RI VWDUFK DQG SURWHLQ
LQ VHOHFWHG FHUHD0V DQG TXDOLW\ RI WKHLU IRRG SURGXFWV)RRG &KHP